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No.
FHWA-
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74-65

Report No. FHWA-RD-74-65

PLANNING FOR PEDESTRIAN MOVEMENT AT INTERCHANGES

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R. A. Ferlis and L. S. Kagan

July 1974
Final Report

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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D.C. 20590

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TE
662
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RD-
74-65

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA-RD-74-65	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
PLANNING FOR PEDESTRIAN MOVEMENT AT INTERCHANGES

5. Report Date
July 1974

6. Performing Organization Code

7. Author(s)
R. A. Ferlis and L. S. Kagan

8. Performing Organization Report No.

9. Performing Organization Name and Address
Peat, Marwick, Mitchell & Co. & RTKL Associates, Inc.
1025 Connecticut Avenue, N.W.
Washington, D. C. 20036

10. Work Unit No.

11. Contract or Grant No.
DOT-FH-11-7966

13. Type of Report and Period Covered
Final Report

12. Sponsoring Agency Name and Address
Offices of Research and Development
U.S. Federal Highway Administration
U.S. Department of Transportation
Washington, D.C. 20590

14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contract Manager; W. S. Adams (HRS-41)

16. Abstract

This report provides highway and traffic engineers with an understanding of the basic considerations necessary to plan effective pedestrian accommodations at urban freeway interchanges. The individual design components used to facilitate pedestrian movement are evaluated on the basis of their impacts on pedestrians and on vehicle flow. Case studies of existing interchanges illustrate common problems and potential solutions. A general approach to the design and evaluation of pedestrian facilities is suggested.

Dept. Of Transportation
OCT 2 1974

H-P-4
8

17. Key Words
Pedestrians, Pedestrian facilities, Cost/benefit analysis, Urban planning, Urban freeway

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	111	

Form DOT F 1700.7 (8-69)

Form FHWA 121 (Rev. 7–72)

UNITED STATES GOVERNMENT

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Memorandum

DATE: MAR 24 1975

In reply refer to: HRS-41

SUBJECT: Transmittal of Research Report No. FHWA-RD, 74-65 "Planning for Pedestrian Movement at Interchanges"

FROM : Director, Office of Research

TO : Regional Federal Highway
Administration
Regions 1, 3-10

Distributed with this memorandum is the subject report with immediately implementable results. This report will be of interest to highway and traffic engineers and transportation planners. The report consolidates research results and experience gained from field observation into a guide for the design of pedestrian accommodations at urban interchanges. The approach to design is applicable to existing as well as to new facilities.

The report enables the highway design engineer to select and evaluate the effectiveness of a set of pedestrian components as applied to a particular interchange configuration. The impacts which result from the use of individual pedestrian components have been identified and, whenever possible, reduced to quantitative measurement. Minimum data requirements have been determined and an evaluation methodology proposed. In addition, a series of detailed analyses of the effectiveness of pedestrian accommodations at existing interchanges have been presented to provide understanding of the interrelationships among the design components.

The set of factors which must be taken into consideration when designing pedestrian accommodations at interchanges are enumerated. As such, this report serves as a supplement to the more general compasison report prepared by Peak, Marwick, Mitchell & Company and TRKL Associates, Inc. entitled, A Comparison of Costs and Benefits of Facilities for Pedestrians. Although the intent of this report is to permit the selection and effective application of pedestrian design elements, it does not provide detailed engineering specifications or attempt to suggest warrants for pedestrian treatment at urban freeway interchanges.

Distributed with the memorandum are sufficient copies of the report to provide a minimum of four copies to each regional office, two copies to each division office, and four copies to each state highway agency. Direct distribution is being made to the division offices. Additional copies for official use may be requested from Mr. David Solomon, Chief, Environmental Design and Control Division, FHWA, HRS-40, Washington, D. C. 20590. Additional copies for the public are available from the National Technical Information Service, Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151. A small charge will be imposed for each copy ordered from NTIS.

D. Solomon
for Charles F. Scheffey

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I. INTRODUCTION

1.1 BACKGROUND

Although freeway interchanges are implemented to facilitate the movement of heavy vehicle traffic volumes, the urban interchange is often subjected to substantial pedestrian movement as well. There are several reasons why this occurs. Urban freeways have been built to serve areas of traditionally high activity and pedestrian trip generation such as central business districts. Even when the highways are located in lower density areas, the presence of the facility itself can stimulate additional development. In situations where cross streets have been terminated by the implementation of the freeway, pedestrian traffic may be focused on the remaining crossing points such as at interchanges. The increasing use of highway right-of-way for mass transit can also result in substantial pedestrian flows within the interchange, particularly in peak traffic periods. The competing needs of vehicles and pedestrians result in the basic conflict problem at urban interchanges.

The provision of accommodations for pedestrian movement can impact safety, vehicular impedance, and pedestrian impedance at the interchange. Facility designs which require pedestrians to cross ramps with heavy vehicle flows without the benefit of traffic control devices result in primary points of conflict between vehicles and pedestrians. Additional points of conflict occur when pedestrians disregard the planned provisions and impinge upon the vehicular domain. If traffic control devices are supplied to facilitate pedestrian movement across the interchange, vehicle flow may be subjected to a level of impedance which is incompatible with the primary objectives of freeway travel. Typical provisions for pedestrian movement inflict substantial inconvenience to pedestrians. Although this may not be unreasonable due to the function of the interchange and the generally low volume ratio of pedestrians to drivers, the consequence may be reduced pedestrian utilization of the provided accommodations and increased safety hazards.

The design of pedestrian accommodations which are responsive to the needs of both drivers and pedestrians is complicated by several factors. Origin-destination and volume data for pedestrian movement is typically not available to the design engineer. Even if the necessary data were available, there are few standards or examples of pedestrian design treatments; consequently, the highway designer is not aware of the options. The basic lack of understanding of pedestrian needs and behavior results are poor information on the effectiveness of alternative pedestrian design treatments. In addition, the critical operational problems associated with the accommodation of the heavy vehicular flows commonly encountered at interchanges can make the highway engineer reluctant to risk major traffic disturbances in order to facilitate pedestrian movement.

These limitations in the design process are evident in the existing pedestrian accommodations at urban interchanges. In many cases, no provisions have been made for pedestrian movement; uncontrolled crossing locations exhibit critical limitations on visibility or require excessive pedestrian waiting times. Even when extensive accommodations such as pedestrian overcrossings have been provided, the inconvenience associated with the use of the facility and the lack of appropriate countermeasures (defined for the purposes of this report as physical restraints on pedestrian movement) result in deviation from the prescribed pathway and the consequent frustration of the design objectives.

1.2 USE OF THE REPORT

This report is intended for use by highway and traffic engineers and transportation planners. Its purpose is to consolidate research results and the experience gained from field observation into a guide for the design of pedestrian accommodations at urban interchanges. The approach to design is applicable to existing as well as to new facilities.

This report enables the highway design engineer to select and evaluate the effectiveness of a set of pedestrian components as applied to a particular interchange configuration. The impacts which result from the use of individual pedestrian components have been identified and, whenever possible, reduced to quantitative measurement. Minimum data requirements have been determined and an evaluation methodology proposed. In addition, a series of detailed analyses of the effectiveness of pedestrian accommodations at existing interchanges have been presented to provide understanding of the interrelationships among the design components.

The set of factors which must be taken into consideration when designing pedestrian accommodations at interchanges are enumerated. As such, this report serves as a supplement to the more general comparison report prepared by PMM&Co., and RTKL Associates, Inc.

entitled A Comparison of Costs and Benefits of Facilities for Pedestrians.(15) Although the intent of this report is to permit the selection and effective application of pedestrian design elements, it does not provide detailed engineering specifications or attempt to suggest warrants for pedestrian treatment at urban freeway interchanges.

1.3 ORGANIZATION OF THE REPORT

Chapter 2 suggests a basic approach to facility design. Pedestrian components, classified by function, are individually evaluated and the impacts of their application identified. In addition, a comprehensive set of facility evaluation criteria are suggested.

Chapter 3 documents the results of four case studies of urban interchanges. The facilities and associated traffic characteristics are described, the effectiveness of their pedestrian accommodations analyzed, and an improved set of pedestrian provisions suggested.

2. EVALUATION OF PEDESTRIAN SYSTEMS

The provision of facilities to accommodate pedestrian movement at urban freeway interchanges must be guided by the requirements of the particular situation. No individual design approach is appropriate for every case. Pedestrian movement, although important, is only one of several factors which must be considered in the selection of an interchange configuration. In many cases, the overall characteristics of the facility are governed by the need to retain compatibility with the remainder of the freeway system.

The intent of this chapter is to facilitate the selection of appropriate pedestrian elements to complement vehicle related interchange elements, as applied to specific physical and traffic conditions. Because of the importance of case-specific variables (e.g., vehicular traffic flows, signal phasing) to the performance of the pedestrian design components, a generalized evaluation approach is used. The effectiveness of the individual components have been assessed both on the basis of existing research as well as the experience gained during the case studies of actual interchanges.

2.1 APPROACH TO PEDESTRIAN FACILITY DESIGN

Urban freeways evolved directly in response to the needs of vehicular traffic flow. Because of this orientation, the needs of pedestrian movement at interchanges have typically been ignored or treated only superficially. A more rigorous treatment of pedestrian problems is now being demanded due primarily to an increased awareness of the pedestrian safety hazard.

2.1.1 Need for Planning

The state-of-the art of pedestrian planning is presently neither as developed as comparable vehicular planning nor as widely practiced. As a consequence, pedestrian movement is not recognized as an important input to the interchange design process. The need for planning is particularly important in the urban setting where heavy pedestrian flows are commonly encountered.

The implementation of an urban freeway can induce greater pedestrian flows. In situations where cross streets are terminated at the freeway right-of-way, pedestrian movements will be channelled to the remaining crossing points. The increasing use of freeway space for transit needs can also substantially increase pedestrian flows; this is particularly true when bus stops or station access points are placed directly within the confines of the interchange. The increased regional access provided by an urban freeway can stimulate the development of high-density land uses in proximity to the interchanges, thereby generating unrecognized heavy pedestrian volumes.

2.1.2 Data Requirements

The selection of pedestrian elements must be based on the particular requirements of the situation. If the interchange under consideration already exists, data may be assembled from routine monitoring activities (e.g., vehicle volumes, accident experience), physical inventory of the facility elements, and small-scale field studies (e.g., pedestrian volumes and pathway utilization). Whether the interchange has already been constructed or not, however, additional data to describe future conditions must also be synthesized.

The basic set of data items needed to effectively evaluate the impact of pedestrian facilities is listed in Table 1. Items associated with the first three categories are largely self-explanatory and are typically available to the design engineer. The pedestrian-related items, in most cases, will have to be developed through field measurement or estimated from projected land use in the vicinity of the interchange. Measures of pathway utilization and effectiveness of control devices can obviously only be taken at interchanges already in operation.

2.1.3 General Design Strategies

Three strategies have been identified which have the potential of alleviating pedestrian/vehicle conflicts:

- increase pedestrian and driver awareness;
- control pedestrian movement; and
- control vehicle movement.

The first technique can be used to facilitate pedestrian crossings of vehicle traffic streams. Design treatments which enable drivers to anticipate pedestrian movement or which enhance visibility for drivers and pedestrians fall into this category. The second strategy includes the provision of pedestrian pathways, grade separated structures (i.e., overpasses), and countermeasures to restrict pedestrian incursion onto

Table 1. Data Requirements

Location	Physical site characteristics
	Land use
	Accident experience
Interchange Characteristics	Type of facility required
	Ramps
	. placement
	. free flow/controlled
	. width of roadways
	Crossroad characteristics
	Traffic control devices
	. type
	. phasing
	. coordination
	Transit facilities
	Pedestrian elements
Vehicle Movement	Ramp volumes
	. daily
	. peak
	Crossroad volumes
	. daily
	. peak
	Movement patterns
	Speeds at pedestrian crossings
Pedestrian Movement	Trip-maker characteristics (e.g., elderly, children)
	Volume
	. daily
	. peak
	Movement patterns
	. pathway utilization
	. desire lines of travel
	. effectiveness of control devices

the vehicle roadways. The third strategy involves the restriction of vehicle movement to facilitate pedestrian movement through the interchange (e.g., use of pedestrian-actuated traffic signals).

These basic design approaches can be employed either individually or in combination, depending on the interchange configuration and traffic characteristics. If the interchange under consideration already exists, the basic problems can be identified from the assembled data (e.g., accident history) and from direct field observation of the facility. The design strategies selected should address these specific problems.

2.2 COMPONENT EVALUATION

To provide assistance in the selection of appropriate pedestrian-related design elements, a comprehensive inventory of operational elements was performed. The components were categorized in accordance with the three basic design strategies identified in Section 2.1.3.

The effectiveness of each pedestrian component was assessed on the basis of a review of relevant research and the experience gained from the observation of actual interchanges. Three categories of impacts were identified as resulting from the use of the components: safety; vehicular impedance; and pedestrian impedance. Each design element was subjectively evaluated for each of the impact categories, if applicable. The design elements and their associated impacts are illustrated in Table 2. Whenever possible, quantitative measures were proposed to facilitate comparisons with alternative components.

2.2.1 Pedestrian Informational Signs

Informational signs can be used to direct pedestrians through interchanges to alternative destinations. These aids are especially useful for interchanges which are spatially extensive or complex.

Safety

Directional signing can produce positive pedestrian safety benefits in cases where confusion over pathway identification or route choice results in pedestrian deviation from the prescribed pathway. In addition, more attention can be paid to potential crossing conflicts rather than path selection.

Table 2. Component Evaluation

		Safety	Vehicular Impedance	Pedestrian Impedance
Increase Pedestrian/ Vehicle Awareness	pedestrian informational signs	X		X
	pedestrian crossing signals	X	X	X
	vehicle warning signs	X		
	illumination	X	X	X
Control Pedestrian Movement	marked crosswalks	X	X	X
	regulatory signs	X		
	sidewalks	X		X
	channelization	X	X	X
	pedestrian barriers	X	X	X
	pedestrian overpasses/ underpasses	X	X	X
Vehicle Impacting TCD's	uncontrolled crossing	X	X	X
	protective barriers	X		
	speed regulation	X	X	X
	stop signs			
	fixed-time/vehicle-act. signals	X	X	X
	pedestrian actuated signals	X	X	X

NOTE: An 'X' identifies a significant impact associated with the use of a pedestrian component.

Pedestrian Impedance

Signs which provide pathway guidance can lessen pedestrian impedance. Concise directions will enable the unfamiliar pedestrian to take the most direct route through a complicated interchange; this is especially helpful at night. The information should also enhance the pedestrian's orientation. Informational signs should stimulate utilization of the planned pathways.

2.2.2 Pedestrian Crossing Signals

Signal indications of the "WALK/DON'T WALK" type are generally used in conjunction with traffic signals to provide information to pedestrians as to when to cross the roadway. These devices are especially useful for situations where wide roadways must be traversed or where multi-phase signal operation and/or channelization are employed.

Safety

Pedestrian crossing signals can provide pedestrians with better information on impending signal changes than can be derived from the standard vehicle-oriented displays. These indications can therefore reduce the possibility of pedestrians being stranded in the roadway when vehicle movement commences. Crossing signals can also be useful to control pedestrian movement where multi-phase signal operation is applied. However, as with all regulatory devices, the safety benefits accrue only if pedestrians comply with the advice. If impedances are preceived (e.g., delays from excessive cycle lengths) and/or disregard of the control device is feasible (e.g., the perceived crossing distance is small) pedestrian behavior and, consequently, safety may not be affected. (4)

Vehicular Impedance

Under certain conditions, the use of pedestrian crossing indications can affect vehicular delay (19); if pedestrians are excluded from the roadway during a portion of the vehicular green time, vehicle impedance can be diminished. Alternatively, the walk signals can encourage pedestrian use of a crosswalk, thereby inhibiting vehicle flow.

Pedestrian Impedance

Pedestrian advisory signals can benefit pedestrians by simplifying the decision to cross at a signalized intersection. The indications can also encourage pedestrians to force vehicles to yield during the

"WALK" periods. However, if the signals are used to restrict pedestrian movement in order to facilitate vehicle flow, pedestrian delay can be substantially increased.

2.2.3 Vehicle Warning Signs

Warning signs are appropriate whenever unexpected hazards are present; since pedestrian movement at freeway interchanges is typically not anticipated by drivers, warning signs may be warranted. The signs may also be supplemented by warning lights to increase the noticibility of the sign.

Safety

Warning signs are effective in the prevention of pedestrian accidents only to the degree to which drivers respond to the advice. These devices should increase drivers' awareness of pedestrian movement and thereby render positive safety benefits; however, it is probably unrealistic to assume that the provision of warning signs alone will effectively counteract safety hazards caused by inadequate design (e.g., insufficient sight distance, poor illumination).

2.2.4 Illumination

Illumination at highway interchanges is typically oriented to vehicular needs. Consideration should also be given toward the adequate illumination of pedestrian crossing locations and, if possible, pedestrian pathways.

Safety

It is well documented that the pedestrian accident rate at night is considerably greater than during the day. Although several factors probably contribute to this difference, the impact of poor visibility is certainly of critical importance. A recent study has indicated (9) that illumination can be effective in reducing the nighttime accident rate. Illumination systems at pedestrian crossings should be designed to ensure driver identification of the crosswalk itself as well as pedestrians in the vicinity of the crossing. Research has shown (8) that the area immediately adjacent to the crosswalk is particularly hazardous because pedestrians are not anticipated; these areas must also be illuminated whenever possible. The illumination system in the general area of pedestrian crossings must be carefully designed to minimize glare and the consequent deterioration of driver visibility of pedestrians. The provision of pathway illumination may result in fewer pedestrian deviations--intentional or otherwise--from the prescribed path. In addition, pathway lighting can result in greater pedestrian security from criminals.

Vehicular Impedance

Illumination at freeway interchanges has only positive impacts on vehicular traffic. These benefits include improved traffic operations, safety, and greater driver comfort.

Pedestrian Impedance

Provision of adequate lighting at freeway interchanges also benefits pedestrians, particularly if pedestrian pathways are illuminated as well. In addition to increased comfort because of enhanced route orientation, improved visibility of the pathway, and (possibly) less tension due to easier identification of vehicle trajectories at crossing points, pedestrian adherence to the prescribed pathway may be intensified.

2.2.5 Marked Crosswalks

Painted crosswalk markings are typically used to delineate the pedestrian pathway across streets. They are intended to direct pedestrian movement and, when used without traffic signal control, to provide pedestrians opportunities to cross and to alert drivers to the potential presence of pedestrians.

Safety

Although painted crosswalks are generally implemented to enhance pedestrian safety, research experience has indicated (6) that the pedestrian accident rate may be greater than in comparable unmarked crosswalks at intersections without traffic signal control. Pedestrian confidence that vehicles will yield the right-of-way may not be warranted due to circumstantial factors (e.g., poor visibility, excess vehicle speed, poor pavement conditions). There is also evidence that the area immediately adjacent to the crosswalk may be more dangerous (8) because pedestrian movement would not be anticipated by drivers. Irresponsible pedestrian use of the crosswalk may also result in increased rearend vehicular accidents.(3) For these reasons, the installation of marked crosswalks at unsignalized intersections must be carefully considered for each individual application. However, marked crosswalks can be effectively used in conjunction with traffic signals to safely conduct pedestrians through complex intersections.

Since the safety of pedestrian crosswalks is directly related to driver behavior, it can be assumed that crosswalk effectiveness will vary according to local traffic characteristics and laws.

Vehicular Impedance

A recent study (20) has indicated that installation of an unsignalized crosswalk will not impede vehicle flow at low pedestrian volumes. However, at higher pedestrian flows, vehicle delay can increase substantially.

Pedestrian Impedance

At crossings which are not controlled by traffic signals, pedestrian delay can be reduced by the addition of a marked crosswalk. Painted crosswalks are more effective in reducing pedestrian delay for conditions of heavy vehicle flow.

2.2.6 Regulatory Signs

One of the most common countermeasures used to control pedestrian movement is the regulatory sign. These devices are frequently used to exclude pedestrians from areas considered to be unsafe or where their intrusion will inhibit vehicular movement. Prohibitive signing is employed to direct pedestrians to alternate crossing locations and to restrict their use of particular areas (e.g., vehicle-dominant interchange spaces, freeway shoulders).

Safety

The safety benefits to be derived from regulatory signing accrue in direct proportion to the degree to which pedestrians conform to the advice. Experience has shown that pedestrian disregard of advisory signing is directly related to the perceived impedance associated with compliance. For example, if pedestrians are requested to follow a less direct route for reasons of safety and no other countermeasures (e.g., barriers) are applied, some amount of unsafe behavior can be expected.

2.2.7 Sidewalks

Sidewalks or paved pedestrian pathways are the primary component of the pedestrian system at freeway interchanges. Pathways must be provided and should be of sufficient width to accommodate the maximum present and anticipated future pedestrian volumes. The paths should be clearly differentiated from other highway-related components (e.g., barrier curbs on bridges and ramps) and provided with appropriate directional signing if required. The actual placement of sidewalks should be responsive to several potentially conflicting requirements: maximize the spatial separation of vehicles and pedestrians, follow the most direct route through the interchange, minimize vertical changes in grade, avoid opportunities for pedestrian disregard of the prescribed pathway, facilitate integration with other pedestrian design components, and cross vehicular roadways at points of minimum conflict.

Safety

Since pathways are literally the backbone of the pedestrian system, the attributes of the pathway will have substantial impact on the overall performance of the pedestrian system. If the pathway is used by pedestrians, the effectiveness of the overall design will determine the magnitude of the safety benefits which will accrue. However, if pedestrians disregard the prescribed route, potential safety benefits to be derived from the other design components (e.g., pedestrian-actuated traffic signal, pedestrian overpass) will not be realized.

Pedestrian Impedance

The provision of well-designed pedestrian pathways can benefit pedestrians by directing their movement through complex interchanges and permitting relatively comfortable walking conditions in inclement weather (i.e., absence of mud). However, design considerations may dictate a circuitous path, thereby increasing pedestrian travel time. Vertical changes in grade necessitated by topological or roadway requirements can substantially increase the level of walking effort and consequently reduce the level of utilization.

2.2.8 Channelization

Refuge islands are typically used to provide space within the roadway to safely store pedestrians who are unable to cross in a single movement. Protective islands may be needed to facilitate vehicular or pedestrian traffic movement at either uncontrolled or signal controlled crossing locations. The islands should be protected by barrier curbing. Marked crosswalks can be used to direct pedestrian movement through the intersection where confusion over pathway identification could arise.

Safety

The use of pedestrian refuge islands can result in significant safety benefits. The structure itself can afford pedestrians some protection from vehicle encroachment; however, the pedestrian may be forced to wait in a more vulnerable location than at the edge of the roadway. At uncontrolled crossings, heavy traffic and long pedestrian crossing times may result in inadequate gaps in the traffic stream; the provision of a refuge could result in increased adequate gaps, perhaps reducing the need for pedestrian risk-taking.

Vehicular Impedance

At locations controlled by traffic signals which accommodate large pedestrian volumes, refuge islands can provide increased flexibility to efficiently control vehicle flow. In situations where wide roadways dictate long pedestrian crossing times, provision of a center island can reduce the pedestrian crossing interval, thereby permitting an increase in the usable green time. Channelizing islands can also be used to implement multi-phase signal operation. In either case, vehicular capacity can be increased while delay is decreased.

Pedestrian Impedance

The provision of refuge islands at an uncontrolled crossing can significantly decrease pedestrian delay (16), particularly in situations where vehicle flow is heavy or pedestrian crossing times are great. When islands are used in conjunction with traffic signals, however, the greater flexibility in signal phasing afforded by channelization can be used to enhance vehicle flow at the expense of additional pedestrian delay. Signal operation which forces pedestrians to cross the roadway in stages can significantly increase pedestrian delay.

2.2.9 Pedestrian Barriers

The propensity of some pedestrians to disregard regulatory signing and basic traffic laws necessitates the use of physical barriers to pedestrian movement in certain situations. When properly designed, barriers (e.g., fencing, landscaping, bollards) are the most effective countermeasures used to control pedestrians. These and other pedestrian countermeasures are discussed in reference (2). The barrier must be continuous; pedestrians will use gaps intended for intersecting roadways, if available, and will circumvent a barrier which does not extend sufficiently further than the prescribed pedestrian pathway.

Safety

Pedestrian barriers, because of their effectiveness in controlling pedestrian movement, have a substantial impact on the safety of an interchange configuration. These design components can potentially exclude pedestrians from vehicle-dominant areas of the facility. By channelling pedestrian movements, the advantages of vehicle-impacting traffic signals or pedestrian overpasses can be fully exploited; the provision of these countermeasures is of primary importance to the effectiveness of the other pedestrian design components. Care must be taken to ensure that the pedestrian barrier does not sacrifice vehicle and pedestrian visibility, however. The barrier system must be designed to avoid hazard to drivers (e.g., use of breakaway supports). Barriers may force motorists from disabled vehicles to assume greater risks by traveling along the roadways.

Vehicular Impedance

The provision of pedestrian barriers should have only a beneficial effect on vehicle flow. Because pedestrians are forced to cross only at designated locations, pedestrian and vehicle movement can be more effectively controlled with traffic signals or pedestrian/vehicle separation. Driver convenience should also be enhanced because of the absence of unexpected pedestrian incursions on the roadway.

Pedestrian Impedance

As with most countermeasures used to control pedestrian movement, physical barriers constrain certain types of pedestrian behavior. The barriers may enforce utilization of a pathway that is significantly less direct than the unrestricted alternative path. The provision of fencing along the perimeter of the interchange will prohibit pedestrian crossings of the freeway; however, the barrier may also force stranded motorists to travel greater distances to secure assistance.

2.2.10 Pedestrian Overpasses/Underpasses

Spatial segregation of pedestrian and vehicle movements by the use of bridges or underpasses would be the ideal way to ameliorate the pedestrian/vehicle conflict problem if construction cost were not a consideration. A previous report (15) analyzed this method of accommodation in great detail. The design attributes of the facility itself as well as the effectiveness of the complementary pedestrian components (i.e., countermeasures) will determine the level of pedestrian usage and the consequent success of the system. These structures may be used to move pedestrians from one side of a complex directional interchange to the other. Alternatively, they may be used to facilitate pedestrian movement across critical elements of the interchange, (e.g., ramps which are subject to heavy vehicular volumes or for which safe pedestrian crossings are infeasible).

Safety

Although pedestrian overpasses and underpasses have the potential of eliminating the safety problem, the benefits from reduced hazards are contingent upon pedestrian utilization of the system. Pedestrians who choose to disregard the accommodation may face increased accident risk because their intrusion onto the roadway may not be anticipated by drivers and because the prohibited crossing location may not satisfy pedestrian safety requirements (e.g., visibility may be restricted).

Vehicular Impedance

The spatial separation of vehicles and pedestrians can significantly benefit vehicular flow. In situations where the accommodation of pedestrian movement necessitates the provision of vehicular control devices (e.g., traffic signals), the implementation of pedestrian over- or under-passes can substantially reduce vehicle delay.

Pedestrian Impedance

The extent to which pedestrian impedance is affected by the provision of a bridge or underpass is directly related to the design of the facility and other site-specific variables. If pedestrians are forced to use a less direct route or one which entails substantial change in elevation, pedestrian impedance may actually be increased. However, if heavy vehicular traffic necessitates substantial pedestrian delays if crossings are made at-grade, the provision of spatial separation can reduce pedestrian delay.

2.2.11 Uncontrolled Crossings

The uncontrolled pedestrian crossing is commonly encountered in situations where pedestrian volumes are light and free-flow interchange ramps are employed. Because of the problems associated with this treatment (as discussed below), it is of limited applicability. The uncontrolled crossing can usefully be considered as the "do nothing" alternative or base case against which the more sophisticated control methods can be compared.

Safety

The uncontrolled crossing makes no provision for pedestrian safety from vehicular traffic. Pedestrians are obliged to wait for gaps in the traffic stream; under heavy vehicle flows, pedestrians may be tempted to accept dangerously short gaps in order to avoid long delays. Because pedestrian movement is not anticipated by drivers, crossing mistakes may be costly. Good visibility by drivers and pedestrians must be provided for safe operation of the crossing.

Vehicular Impedance

Unless pedestrians are aggressive in forcing vehicles to yield, vehicle delay is primarily dependent on other traffic considerations (e.g., merging with other vehicle flows). Because no control devices impede vehicular movement, delays will remain low regardless of the pedestrian volumes.

Pedestrian Impedance

Pedestrian delays can be substantial for uncontrolled crossings, particularly where there are heavy traffic volumes or wide roadways. The average delay per pedestrian crossing a ramp can be estimated by the equation given in Appendix 1.

2.2.12 Protective Barriers

Physical barriers have historically been used to prevent vehicles accidentally leaving the roadway from colliding with roadside obstacles. Since the guardrails actually pose a physical hazard themselves, their use has been limited. Guardrails can also be used, however, to afford protection to pedestrians on pathways adjoining the highway.

Safety

Properly designed guardrails can effectively provide protection to pedestrians from errant vehicles. In addition to the potential collision hazard to vehicles, however, the guardrails can also obscure visibility and therefore decrease safety for both vehicles and pedestrians. The trade-offs between driver and pedestrian safety must be carefully considered for each individual application. Whenever possible spatial separation should be substituted for the use of physical barriers; the placement of pedestrian pathways should be as far as practical from parallel roadways. Fortunately, certain typical situations where space is constrained (e.g., bridges, tunnels) require guardrails to protect vehicles; in these cases the barriers will afford pedestrians security from vehicle incursion.

2.2.13 Speed Regulation

The determination of speed limits on interchange ramps is typically based on geometric and vehicular traffic characteristics. However, vehicle speed can also impact pedestrian movement. Low speed limits can reduce problems of poor driver visibility of pedestrians in certain situations.

Safety

The specification of low speed limits can yield safety benefits for both pedestrians and motorists in certain situations. Speed reductions can result in less severe vehicle-vehicle, vehicle-fixed object, and vehicle-pedestrian collisions. Although lower vehicle speeds should increase driver control and thereby enhance safety, motorists exiting the freeway must be adequately warned of the necessity to slow down in order to prevent collisions with slower vehicles on the ramp. For the pedestrian, lower vehicle speeds can result in better estimation of gaps in the traffic stream(13) as well as facilitate vehicle stopping if an inadequate gap is chosen; however, lower vehicle speeds may also encourage pedestrians to take greater risks due to overconfidence. As is the case with other regulatory controls, speed limits are effective only to the degree to which they are obeyed; disobedience of the control mechanism can result in increased hazard.

Vehicular Impedance

The use of low speed limits to facilitate pedestrian movement can have an adverse impact on vehicle flow. If the speed limit is observed, vehicle free flow travel time will be increased. In addition, pedestrian confidence may be enhanced, resulting in a greater number of vehicles being forced to slow or stop. However, in situations where downstream intersections control vehicle flow (e.g., traffic signal, bottleneck caused by merging conflicts) the delay penalty may be slight.

Pedestrian Impedance

Lower vehicular speed limits can reduce pedestrian impedance. Where marked crosswalks are provided, pedestrians may take advantage of the low vehicle speeds and force vehicles to yield, thus decreasing pedestrian delay.

2.2.14 Stop Signs

Stop signs are occasionally used to control traffic flow off interchange ramps where signals are not warranted. Although these control devices could be used at mid-ramp locations to ease pedestrian movement, the poor noticeability of the sign, the magnitude of vehicle impedance, and the inflexibility to changing traffic conditions generally preclude its application.

Safety

When used to control traffic at ramp terminals, the stop sign can increase pedestrian safety over an uncontrolled intersection because vehicles are forced to stop and the need for pedestrians to cross a moving traffic stream is eliminated. However, as in the uncontrolled situation, drivers' attention maybe diverted to the vehicular merge thereby endangering pedestrian safety--particularly when the direction of pedestrian movement is counter to the vehicular movement on the crossroad. Also, pedestrians are encouraged to cross in front of vehicles despite the clear potential for the vehicles to violate the control device. If vehicles impinge upon the crosswalk, pedestrians may be tempted to circumvent the obstruction, therefore increasing the hazard from vehicles on the crossroad or on the ramp.

Vehicular Impedance

By definition, the stop sign impedes vehicular movement; this is particularly true where cross street volumes are heavy. In addition, strong pedestrian flows can substantially inhibit the discharge of vehicles from the stop sign. A series of nomographs were developed (10) to estimate vehicular delay at stop signs.

Pedestrian Impedance

Because vehicles are forced to stop at the sign, pedestrians experience little or no delay from vehicles which conform to the control method. However, if vehicles illegally block the crosswalk, pedestrians may incur delays.

2.2.15 Fixed-Time/Vehicle-Actuated Signals

Traffic signals are frequently used to control traffic movements at the intersections of interchange ramps with cross streets. Both fixed-time and vehicle-actuated signals are typically installed on the basis of vehicular volume warrants. Signal phasing, interval durations, and cycle lengths are generally determined to facilitate vehicular movement; however, pedestrian needs may control minimum interval durations or maximum cycle lengths, particularly where multi-phase operation is utilized.

Safety

Among the factors which influence the relationship between traffic signals and safety for a particular situation are the degree of coordination with upstream signals, phasing, channelization, and the visibility of the signal. Despite the importance of these location-specific factors, the installation of properly warranted signals can be expected to decrease the accident hazard to vehicles (5). It has also been shown (1,10) that the provision of traffic signals can increase pedestrian safety. It is reasonable to assume that the pedestrian safety benefit is greater for locations with heavy vehicle flow, wide roadways, poor visibility, or which are utilized by pedestrians who have difficulty crossing (e.g., the elderly). Signal timing characteristics can also affect the pedestrian accident hazard. Excessively long cycle lengths or, where storage islands are provided, signal phasing which requires that pedestrians cross in stages can encourage disregard of the control device. An inadequate pedestrian crossing interval or poor advisory control devices (see Section 2.2.2) can result in pedestrians being stranded in the roadway when vehicle movement is to begin. Whenever possible, pedestrians should be allowed to cross free of conflict with turning vehicles.

Vehicular Impedance

The installation of traffic signals can either increase or decrease vehicular impedance, depending on traffic conditions and the effectiveness of the control device. Average delay per vehicle can be estimated by the equation given in Appendix 1 for intersections with light pedestrian flows. Heavy pedestrian flows can impede turning vehicles significantly if pedestrians and vehicles are allowed to conflict (14). In situations where pedestrian needs dictate lengthened signal timing intervals, vehicular delay may increase.

Pedestrian Impedance

Pedestrian impedance at traffic signals is influenced by the signal timing and the degree of pedestrian disregard of the control device. As previously mentioned, excessively long cycle lengths or staged crossing can adversely affect pedestrian delay. An equation which can be used to estimate the average pedestrian delay at an intersection controlled by a simple fixed-time traffic signal is given in Appendix 1.

2.2.16 Pedestrian-Actuated Signals

Two types of pedestrian-activated signals are appropriately used at interchanges. The first type is used at intersections; an actuation by a pedestrian will modify the duration of the signal interval to allow sufficient time for pedestrians to cross the roadway. The second type of signal could be useful at pedestrian crossings which are not at intersections; a pedestrian actuation will, subject to a minimum vehicular green time, cause the signal to stop traffic on the roadway to facilitate pedestrian crossings.

Safety

The utility of a demand-actuated pedestrian phase in conjunction with a fixed-time or vehicle-actuated traffic signal is dependent on pedestrian use of the actuation device; if the device is disregarded, pedestrians may well have insufficient time to cross the roadway. At crossings not located at roadway intersections, however, pedestrian-actuated signals can encourage usage because of their responsiveness to pedestrian demand. This is particularly true at low pedestrian volumes, where crossing requests can usually be satisfied promptly. The provision of pedestrian-actuated traffic signals can reduce safety hazards caused by inadequate visibility, poor driver awareness of pedestrian movement, or an insufficient supply of gaps in the traffic stream. Because actuated signals are demand-responsive, safety disadvantages inherent in traffic signals (e.g., potential for accidents resulting from vehicle stops) are minimized. The signal installation must achieve an especially high degree of visibility to drivers to compensate for the missing clues usually afforded by the presence of intersecting roadways.

Vehicular Impedance

The magnitude of vehicle delay associated with a pedestrian-actuated traffic signal is dependent on the vehicular flow, the pedestrian flow, the minimum signal phase durations, and the physical characteristics of the pedestrian crossing. An equation given in Appendix 1 can be used to estimate the average delay per vehicle in order to facilitate comparison with the delays produced by fixed-time signals.

Pedestrian Impedance

The provision of demand-responsive pedestrian phases for fixed-time or vehicle-actuated traffic signals results in pedestrian delay which is determined primarily by the duration of the signal cycle length (see Section 2.2.15). The amount of pedestrian delay which is produced by a pedestrian-actuated signal not located at a roadway intersection is affected both by the signal timing and the pedestrian volume characteristics. An equation given in Appendix 1 can be used to estimate the average delay to a pedestrian at this type of signalized crossing.

2.3 EVALUATION METHODOLOGY

This evaluation method is oriented toward providing information to assist in the selection of one design alternative over competing alternatives, where each alternative represents a combination of pedestrian components. Although this approach can be useful in the assessment of the advantages and disadvantages assocated with a single alternative, the identification of a base case can illustrate the sensitivity of the individual design criteria under the conditions specified. The evaluation can proceed in two distinct steps:

- The individual alternatives should be rated for each design criterion. This process forces the analyst to consider all of the impacts of a design. Quantitative measures of attainment should be computed if applicable.
- Detailed comparisons should be made between the alternatives. Criteria for which the alternatives are similar can be eliminated and trade-offs between the remaining criteria can be identified.

2.3.1 Design Criteria

The basis of this approach to evaluation is that the relative effectiveness of a particular alternative can be assessed by the application of a set of objective evaluation criteria. A series of criteria were developed to rate an alternative design in four impact areas: safety, vehicular impedance, pedestrian impedance, and facility cost; Table 3 lists the impact areas and their associated evaluation criteria. A binary rating method is suggested for some criteria, with "yes" indicating satisfactory attainment of a criterion (e.g., sufficient sight distance, provision of effective countermeasures, absence of driver attention conflicts). The remaining criteria can be measured either quantitatively (e.g., vehicle delay, number of conflict points) or subjectively (e.g., comfort).

Existence of Countermeasures

The experience gained during the case studies of urban interchanges has indicated the overwhelming importance of effective pedestrian countermeasures to utilization of the system. Countermeasures

Table 3. Evaluation Criteria

IMPACT	CRITERION	MEASUREMENT
Safety	Existence of countermeasures	yes/no
	Number of conflict points	Q
	Exposure to vehicles	Q
	Driver awareness of pedestrians	yes/no
	Sight distance	yes/no
	Illumination	yes/no
	Attention conflicts	yes/no
Vehicle Impedance	Delays	Q
	Stops	S
	Operating cost	Q
Pedestrian Impedance	Delay at crossings	Q
	Directness of path	Q
	Comfort/convenience	S
Facility Cost	Construction cost	Q
	Environmental costs	S

NOTE: Q indicates quantitative measurement
S indicates subjective measurement

must be applied to discourage pedestrian disregard of the prescribed control methods whenever compliance with the control measures is perceived as causing impedance and alternatives are available.

Number of Conflict Points

Conflict points exist wherever pedestrians cross vehicle traffic streams without the benefit of signal control or vehicle/pedestrian separation. These conflicts may originate either from the use of planned pedestrian provisions (e.g., crosswalks) or as a result of pedestrian deviation from the provided pathway. The total number of conflict points can be a useful measure in the evaluation of pedestrian pathways through complex interchanges.

Exposure to Vehicles

Another useful measure closely related to the number of conflict points is pedestrian exposure to vehicles, simply the summation over all (unsignalized) crossings of the products of the vehicle and pedestrian volumes for a given time period. A high value for this index can indicate the presence of heavy vehicle and/or pedestrian traffic at the conflict points. This measure can be used to compare the relative magnitude of pedestrian/vehicle conflicts in alternative interchange designs.

Driver Awareness of Pedestrians

This criterion is appropriate only where uncontrolled pedestrian crossings are used. For a positive score, devices must be provided to ensure driver awareness of pedestrian movement at the crossing location. The selection and placement of these elements, however, must be carefully examined to prevent driver confusion or disregard.

Sight Distance

Drivers must be given sufficient time to effectively respond to the presence of pedestrians or pedestrian-related traffic control devices. At crossing locations not protected by signal control, pedestrians must be given adequate opportunity to perceive gaps in the traffic stream. This mutual awareness is necessary to the safe operation of a pedestrian crossing. Careful attention must be given to the restrictions on sight distances caused by horizontal and vertical curvature, structural elements of the interchange (e.g., bridge components, guardrails), and landscaping. Consideration must also be given to the needs of elderly pedestrians and school children, who walk more slowly and may be more difficult for drivers to see.

Illumination

Adequate lighting of all pedestrian crossings must be supplied. The illumination of pathways should also be considered essential in areas with significant criminal activity.

Attention Conflicts

Since the function of the freeway interchange is to distribute vehicle movement, the need for merging maneuvers and directional signing cannot be avoided. However, these elements of interchange operation can pose significant hazards to pedestrians attempting to cross traffic streams. Unfortunately, the most direct pedestrian path through an interchange is frequently immediately parallel to the crossroad, thus encouraging pedestrians to cross in the vicinity of the vehicle merge. The placement of information signs near pedestrian crossings can similarly distract the driver. The presence of these attention conflicts can potentially increase the safety hazards at pedestrian crossings.

Delay to Vehicles

Delay due to pedestrian-related traffic control can be estimated using the techniques outlined in Appendix 1. Both delay/vehicle and total delay should be computed for each alternative design.

Vehicle Stops

Although the number of vehicle stops can be measured in the field or derived from simulation, a subjective assessment of this measure can often be more easily obtained and used to make comparisons between the relative effectiveness of design alternatives.

Vehicle Operating Cost

Although potentially worthy of consideration, vehicle operating cost can not be accurately estimated for particular situations. However, since operating cost should be highly correlated with vehicle delay, its exclusion from the evaluation structure should not greatly affect the relative effectiveness of the individual alternatives.

Pedestrian Delay at Crossings

The determination of pedestrian delay for different cagetories of crossing is treated in Appendix 1. As in the vehicular case, estimates should be made for both the average delay per person and the total pedestrian delay. It must be recognized that delay can affect safety because pedestrians tend to accept greater hazard when the delay is substantial (11).

Directness of Path

Directness is an important measure of the impedance associated with a pedestrian pathway. This measure can be expressed either as a ratio of ideal vs. pathway distance through the entire interchange or as additional delay, expressed as delay/person or total delay. As is the case at crossings, delay can have a substantial impact on pedestrian utilization of the prescribed facility.

Comfort and Convenience

Where appropriate, the comfort and/or convenience of an alternative design can be subjectively assessed. Although in most cases this criterion will be related to other criteria (e.g., delay, illumination), some facility attributes may not be included. For example, the comfort of a protected walkway or the inconvenience of stairs can be denoted to facilitate trade-off comparisons with other design alternatives. The very consideration of this aspect can enhance understanding of the facility impacts.

Construction Cost

Many of the pedestrian elements cost very little to construct or provide (e.g., warning signs). Other costs may not be very sensitive to combinations of other pedestrian design components; the construction cost of a sidewalk does not depend on the type of crossing control provided. Facility elements such as traffic signals, protective guardrails, pedestrian barriers, and overpasses can exhibit wide cost variations depending on the local conditions. Operating costs for most of the pedestrian components will probably be minimal. Also, since the actual costs of some facility impacts can not readily be determined (e.g., accident cost), comparisons among the alternatives on a strictly cost basis are not practical. In view of this, no attempt has been made to develop a rigorous cost structure; however, a previous study (15) has investigated the costs associated with certain pedestrian facilities. Two approaches can be taken. If the costs associated with the various alternatives are of approximately the same magnitude, the cost aspects can be essentially eliminated from the evaluation. Secondly, if the costs are significantly different, coarse estimates based on the actual situation will probably be sufficient for purposes of evaluation.

Environmental Costs

These costs can be the most difficult to assess. Consideration can be given to the aesthetics of the individual design alternatives. Some pedestrian countermeasures such as restrictive fencing can certainly detract from the visual enjoyment of the interchange. There may also be a cost associated with the curtailment of landscaping to protect sight lines. On the other hand, a pedestrian overpass can be either attractive or unattractive depending on the individual attributes of the structure. Where vehicles are impeded by pedestrians or pedestrian-related traffic control devices, a pollution cost may result; however, this aspect may already be reflected in the other criteria.

2.3.2 Selection of an Alternative

The rigorous application of the evaluation criteria should provide the analyst with relevant information on both the absolute effectiveness of each individual design as well as the relative effectiveness of the alternatives. By this point, serious deficiencies in any of the alternatives should have been identified.

Display of Criteria Measurement

It may be useful to prepare a table which summarizes the scores of each alternative with respect to each of the evaluation criteria and which lists the assumptions concerning traffic characteristics. Criteria which are not applicable or for which significant differences among the alternatives do not exist should be eliminated. Alternatives which do not meet critical criteria (e.g., existence of effective countermeasures, sight distance, illumination) should now be discarded. Table 4 illustrates one form the display might take. In this example, a simple trade-off analysis of total (pedestrian and driver) delay cost against construction cost would probably indicate that alternative 3 dominates alternative 2. It must be understood, however, that the display is not complete; important impacts such as safety can not easily be quantified but must be included in the overall evaluation process.

Identify Additional Alternatives

The analysis approach should increase understanding of the problems and characteristics of the situation being studied. This additional information may, in turn, lead to the identification of additional design alternatives, which may in fact be minor modifications of the original designs. This iterative process may result in more suitable facility configurations.

Table 4. Illustrative Evaluation Matrix

	Uncontrolled Crossings	Signalized Crossings	Partial Pedestrian Overpass	Complete Pedestrian Overpass
Criteria	1	2	3	4
Number of conflict points	4		2	
Exposure to vehicles	50,000		15,000	
Vehicle stops		yes		
Delay/vehicle (sec.)		15		
Total vehicle delay (sec.)		150,000		
Delay/pedestrian (sec.)	12	45	5	
Total pedestrian delay (sec.)	24,000	90,000	10,000	
Construction cost ($)	2,000	12,000	40,000	85,000

x Assumptions: 10,000 vehicles/day
2,000 pedestrians/day

Selection of an Alternative

Using the structure of the evaluation matrix as a basis, the tradeoffs between the various alternatives can now readily be identified. No mechanical procedure, however, can replace the experience and judgment of the analyst. The matrix can only provide usable information to assist in the actual selection.

Examination After Implementation

Because of the utilization problem inherent in the provision of pedestrian accommodations, the facility should be examined after implementation to insure that pedestrians are adhering to the prescribed pathway and observing the control devices. The importance of this procedure is evidenced by the poor effectiveness of many existing pedestrian facilities; the following section addresses this problem.

3. CASE STUDIES OF URBAN INTERCHANGES

3.1 INTRODUCTION

The case study approach was used to examine the effectiveness of existing methods of pedestrian accommodation as evidenced by their application at actual urban freeway interchanges.

3.1.1 Identification of Study Sites

A survey was conducted in the Baltimore-Washington, D.C. area to identify potential interchanges for detailed case study analysis. The interchanges examined either already contained special pedestrian accommodations or exhibited substantial conflict between pedestrian and vehicle traffic. Sketches prepared for each candidate indicated the configuration of the interchange, movement patterns, and pedestrian elements. Eleven of these potential study locations are described in Appendix 2.

Four of the surveyed interchanges were chosen for detailed analysis. Coincidentally, all sites which were selected are located in the Baltimore area; however, these configurations were felt to be representative of the major classes of urban freeway interchange to be found nationwide. Table 5 identifies the locations and major characteristics of these interchanges.

3.1.2 Case Study Method

The effectiveness of the pedestrian accommodations at a particular interchange is dependent on a variety of site-specific characteristics. The procedure utilized for the case studies was guided by the need to identify and measure the relevant interchange elements and traffic characteristics at each site. The studies proceeded in three distinct phases: description of the interchange, analysis of the effectiveness of the interchange components, and the development of illustrative design improvements.

Design of the Interchange

The objective of this phase was to assemble all data pertaining to the interchange which would be needed for the subsequent analysis. Although base maps, traffic volumes, and accident experience for the study sites were obtained from local authorities, most of the information was derived from field observation. Graphical displays were prepared to indicate placement of pedestrian design elements, pedestrian and vehicle movement patterns, and the location of pedestrian/vehicle conflict points within the interchange configuration. Measurements of pedestrian and vehicle traffic flows were also taken.

Table 5. Case Study Sites

Location	Context	Configuration	Pedestrian Accommodation
St. Paul/Mount Royal at I-83	Urban	Exit ramp	Minimal
North Charles at I-83	Urban	Entry ramp	Minimal
Liberty Road at I-695	Suburban	Cloverleaf interchange	Minimal
28th/29th Street at I-83	Urban	Directional interchange	Extensive

Effectiveness of the Interchange Components

In Section 2.1.3, three general design approaches were identified as being potentially able to alleviate conflict situations:

- increase pedestrian and driver awareness;
- control pedestrian movement; and
- control vehicle movement.

The provided pedestrian facilities in each of the case studies were analyzed within the context of these three basic design strategies. Pedestrian/vehicle conflict problems were identified and the effectiveness of the existing accommodations in mitigating these problems was examined.

Illustrative Design Improvements

In order to illustrate how typical pedestrian problems could be addressed, design alternatives were formulated in response to the particular problems identified at each interchange. Although the scope of the study did not permit the detailed analysis which would be required prior to the actual implementation of these illustrative designs, the description of these potential improvements provides guidance on the selection and application of appropriate design components to alleviate certain representative pedestrian movement problems at interchanges. The suggested design changes, which are graphically displayed, are discussed in terms of their conformity with the three basic strategies for improvement: increase of pedestrian and driver awareness; controls on pedestrian movement; and controls on vehicle movement.

3.2 CASE STUDIES

The following sections discuss the results of the case studies of the four urban freeway interchanges.

3.2.1 St. Paul at I-83.

3.2.1.1 Description of the Interchange

This interchange is located on the northern edge of downtown Baltimore. The portion of the interchange which was selected for study was the off ramp from southbound I-83 at the intersection of St. Paul Street and Mt. Royal Avenue.

Context

The Baltimore city traffic network is composed of a series of one-way couplets both in the north-south and east-west axes within the city. These one-way pairs are linked to Baltimore's primary urban expressway (I-83) at various alternating points throughout the northern edge of the city's central area (see Figure 1). This interchange serves as a major access point linking I-83 to two primary downtown streets. Both St. Paul and Mount Royal Avenue serve to deliver heavy volumes of morning peak hour traffic into the downtown area.

The interchange is surrounded by several major land uses which are responsible for generating pedestrian traffic across the two I-83 offramps. Directly to the north is the Penn Station railroad terminal and a residential area. To the south is an area of high-rise offices and

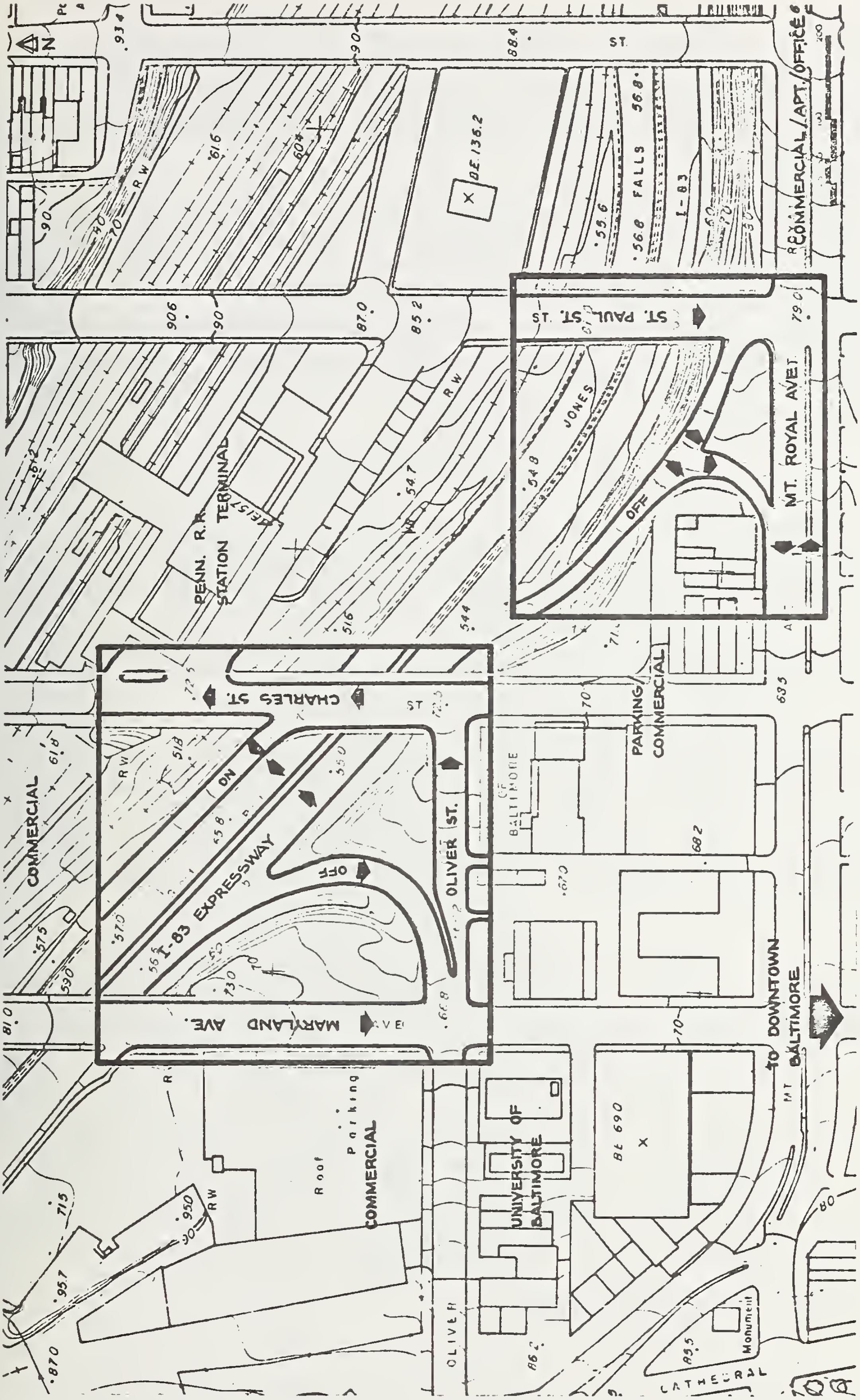


Figure 1. Charles St./St. Paul St. and I-83

apartments along St. Paul Street. West of the interchange along Mount Royal avenue is a commercial complex and the University of Baltimore complex. The area directly east of the intersection between Mount Royal Avenue and I-83 remains vacant and, as a result, minimal pedestrian traffic was observed moving along the north side of Mount Royal Avenue east of St. Paul Street.

The abbuting land uses create a situation of moderate pedestrian volumes along the north side of Mount Royal west of St. Paul Street and along the west side of St. Paul Street in the terminals of the I-83 off-ramps. This foot traffic is continuous throughout the day and is at its peak from 7:00 to 9:00 a.m. due to commuters walking to Penn Station and students walking from parking areas to the University of Baltimore. The abutting land uses, which have been bisected by the depressed expressway, require linkage.

Provisions for Vehicle Movement

St. Paul Street is a major one-way southbound arterial which serves as a primary route for traffic from Baltimore's urban fringe and suburban areas which is destined for the inner city. During peak hours St. Paul has four traffic lanes, although in the vicinity of the I-83 off-ramp the number of lanes is reduced to three to accommodate traffic exiting from the expressway (see Figure 2). The peak traffic volume of 2,500 vph occurs between 7:00 and 8:00 a.m.

Mount Royal Avenue accommodates major downtown cross traffic and provides direct access to other areas north of the downtown. Mount Royal is a four lane arterial, two lanes in each direction, with channelized left turn lanes occurring at several north-south intersecting streets. Volumes of 1,200 vph were observed in each direction during a.m. peak hours.

The I-83 off-ramp is two lanes at its juncture with the expressway and then splits into two single lane ramps, one terminating at St. Paul Street and the other terminating at Mount Royal Avenue. The St. Paul Street terminal is controlled by a traffic signal which allows vehicles from the ramp to enter the arterial immediately before the intersection with Mount Royal. The second branch of the off-ramp curves sharply to become an additional lane on westbound Mount Royal. This terminal, which is free flow, allows merging to occur 190 feet west of the St. Paul intersection. A total volume on the exit ramp of 1,000 vph was observed during a.m. peak hours, with 70 percent of the traffic exiting directly onto westbound Mount Royal Avenue.

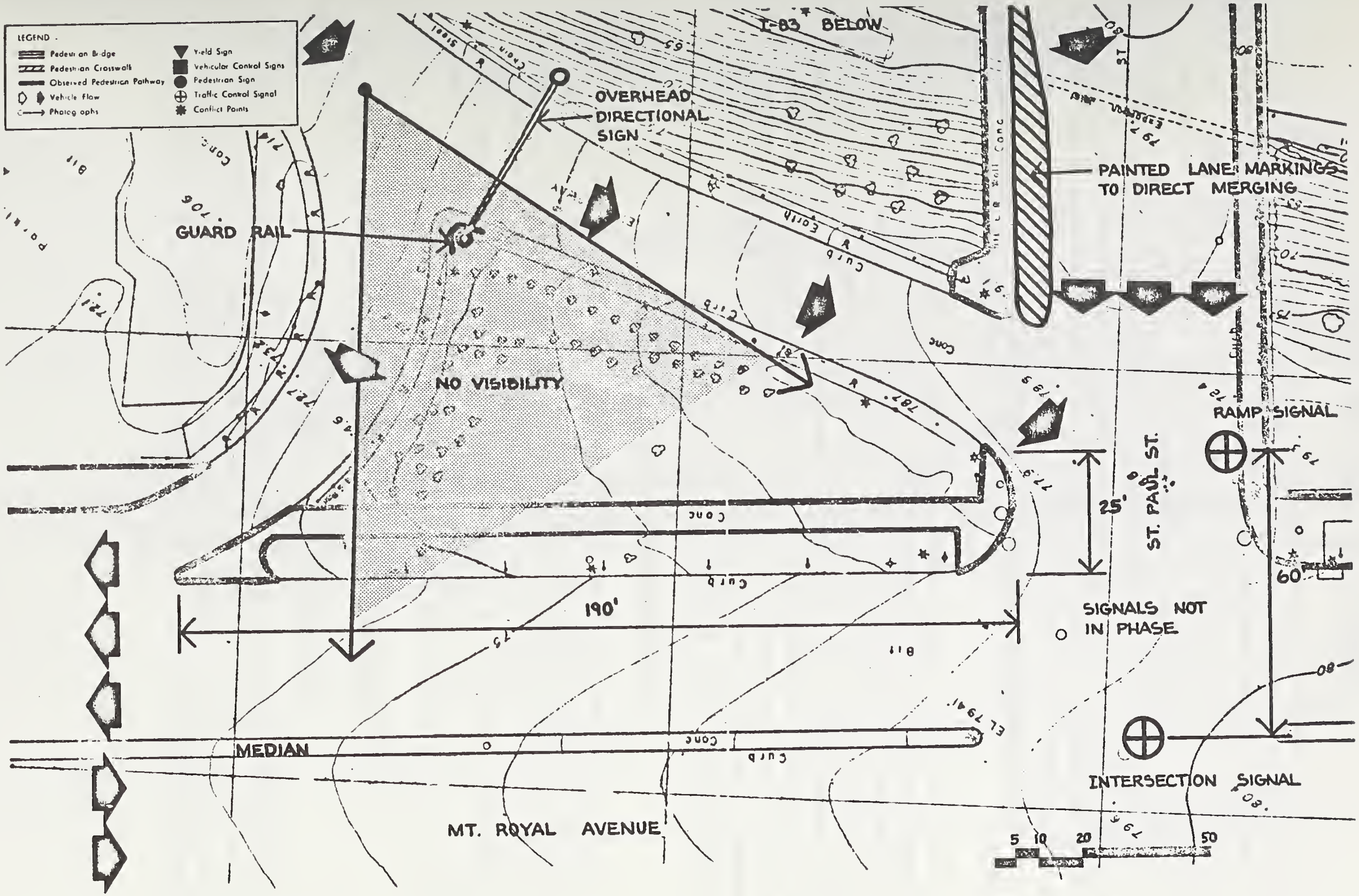


Figure 2. Vehicle movement -- St. Paul St./I-83

Provisions for Pedestrian Movement

Five-foot sidewalks exist along the west side of St. Paul Street and the north side of Mount Royal Avenue where the I-83 off-ramps intersect those streets respectively. The St. Paul-Mount Royal intersection has a 10-foot sidewalk in each of the other quadrants. The island formed by the land enclosed by the two I-83 ramps is fenced for its entire length in the area where it interfaces with the ramps. This area is also heavily landscaped, forming a 6-foot high barrier. The signal located at the terminal of the St. Paul Street ramp provides "WALK/DONT WALK" indications to control pedestrian movement across the ramp. The path is delineated by crosswalk markings. No crosswalk markings are provided, however, at the Mount Royal terminal.

The majority of pedestrian traffic is generated by land use activities north and west of the interchange, resulting in moderate pedestrian volumes (50-70 pph) through the northwest corner of the St. Paul-Mount Royal intersection. The pedestrian desire line for this movement is indicated by a straight line between points (A) and (B) of Figure 3. Because the prescribed pathway along the arterials deviates markedly from the desire line, only 40 percent of the pedestrians observed actually used the sidewalks. The remaining pedestrians chose the shorter route along the ramp roadways.

Pedestrian/Vehicle Conflict Points

Pedestrians moving through the northwestern quadrant of the intersection are in conflict with vehicles only at the free flow ramp terminal at Mount Royal Avenue, if they adhere to the prescribed path and observe the control devices; however, significant numbers of pedestrians disregard the signal. The most significant incidence of conflict occurs on the ramp legs, where the majority of pedestrians choose to travel despite the obvious hazards.

3.2.1.2 Effectiveness of the Interchange Components

Pedestrian/Driver Awareness

The pedestrian/vehicle conflict at the Mount Royal terminal is aggravated by a number of factors. Since there are no warning signs, warning lights, or crosswalk markings, drivers may not anticipate pedestrian movement. The fence and landscape barriers in the median

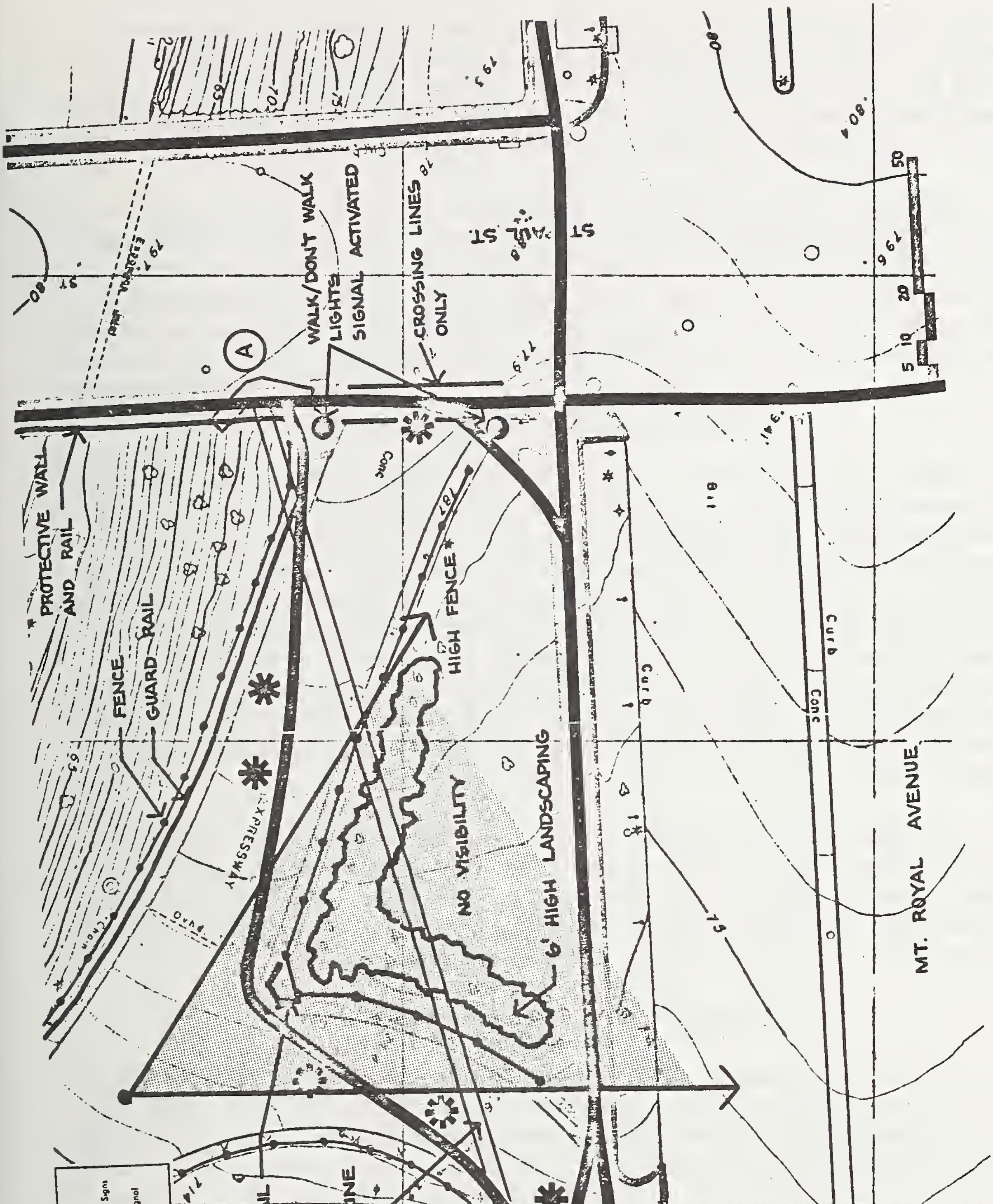


Figure 3. Pedestrian movement -- St. Paul St./I-83

island between the off-ramps and the lower elevation of the roadway restrict driver visibility and create a blind area in the ramp apron along Mount Royal Avenue. Drivers only become aware of pedestrians when they actually step out into the roadway. In addition, drivers may be distracted by westbound traffic on Mount Royal.

The heavy pedestrian movement on the ramps also causes problems. Drivers may not expect pedestrians to be on the ramp roadway. Where the ramp branches, drivers' attention may be focussed on the overhead directional sign, away from pedestrian movement on the ramp. However, due to the anticipated traffic considerations at the ramp terminals, vehicles typically operate at low speeds.

Controls on Pedestrian Movement

Since the location of the provided sidewalk is not along the path of desired pedestrian movement, pedestrians who use the path are inconvenienced by the additional travel distance. This incentive to deviate from the provided pathway is heightened by the existence of a visibly more direct alternative route along the ramps. The fence and landscaping barriers in the median island, although intended to preclude pedestrians from moving diagonally across the interchange, are not effective in preventing that movement. Furthermore, the close proximity of the fence to the ramp forces the pedestrians to walk directly in the roadway where they are continuously exposed to vehicular traffic.

The provision of pedestrian crossing indications (WALK/DON'T WALK lights) at the St. Paul ramp terminal has not prevented pedestrians from violating the traffic signal. This lack of observance may be partially due to the narrow width of the ramp and the consequent availability of acceptable gaps in the traffic stream.

Controls on Vehicle Movement

The traffic signal at the St. Paul Street ramp terminal restricts the flow of traffic exiting to St. Paul Street; although this signal facilitates pedestrian crossings, the installation was probably warranted by vehicle traffic considerations. The Mount Royal Avenue ramp, because it is not controlled, does not significantly impede vehicle movement.

3.2.1.3 Illustrative Design Improvements

An improved method of accommodating pedestrian flow at this interchange is illustrated in Figure 4. A major objective was to control pedestrian movement to prohibit incursion onto the ramp legs.

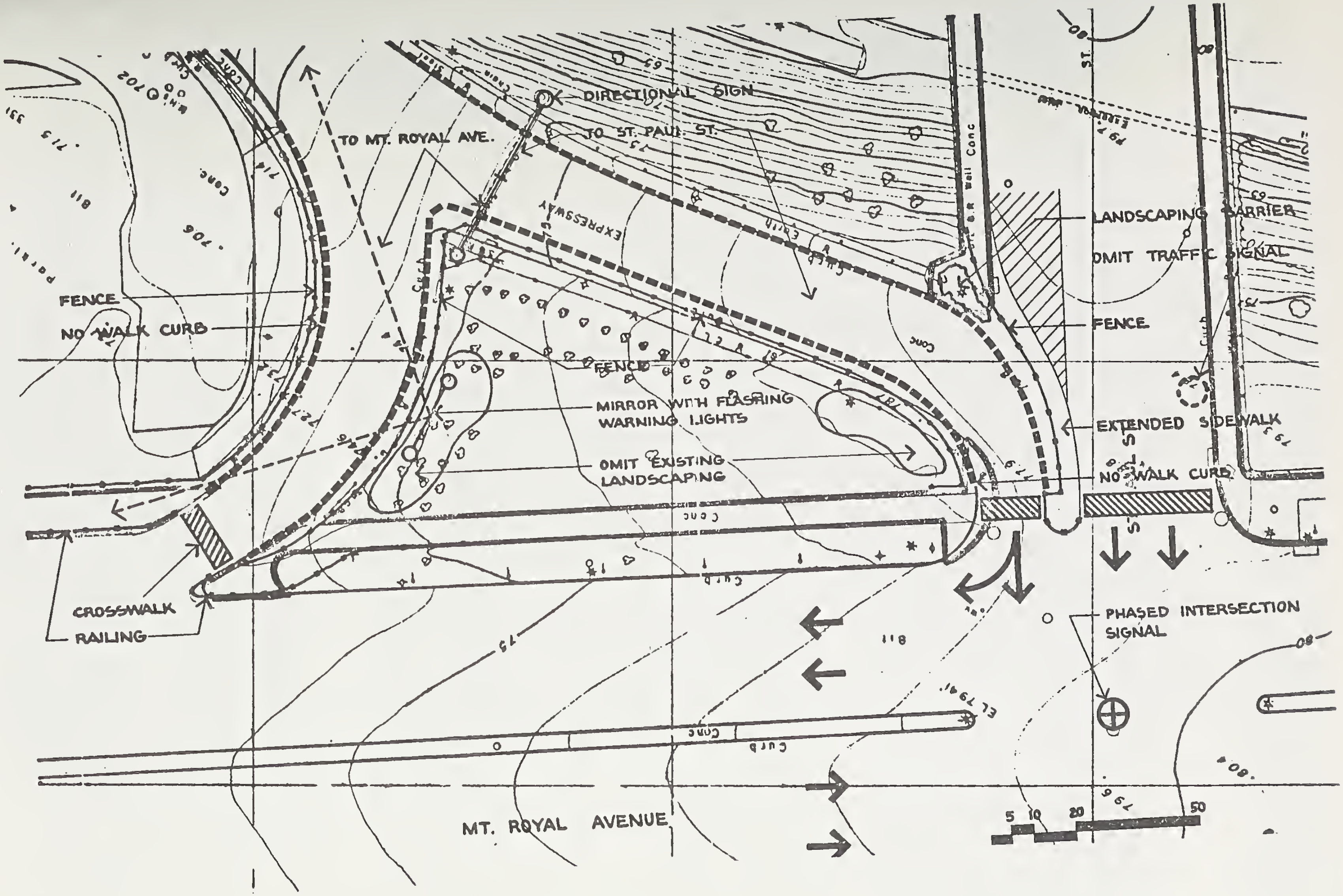


Figure 4. Suggested improvement - St. Paul St./I-83

The design also addresses the conflict problem at the Mount Royal terminal by increasing the awareness of drivers and pedestrians. These measures have resulted in changes in the configuration and operation of the ramp.

Controls on Pedestrian Movement

Since a pedestrian pathway which corresponds to the travel desire line was not considered feasible, it was necessary to provide effective countermeasures to restrict pedestrian movement to the planned accommodations. Extensive fencing has been employed to discourage pedestrian use of the vehicle ramps and to encourage use of the crosswalks. The configuration of the fencing forces pedestrians who still choose to walk on the ramps to travel a significantly longer and more circuitous path than if they used the planned pathway. An additional discouragement to pedestrian movement along the ramps is the barrier curbing designed to be difficult to walk upon. Although the provided pedestrian path is slightly longer than the original (deviant) path along the ramps, pedestrians are not exposed to vehicular traffic. The crosswalk at the Mount Royal Avenue terminal is placed to minimize the crossing distance while the crosswalk at the St. Paul Street terminal, because it is controlled by the traffic signal, allows temporal separation from vehicular traffic.

Pedestrian/Vehicle Awareness

The only intended conflict point is the uncontrolled crosswalk at the Mount Royal Avenue ramp terminal. The provision of flashing amber lights in conjunction with an appropriate warning sign should increase drivers' awareness of potential pedestrian movement. Landscaping in sections of the center island has been omitted to increase the visibility of drivers and pedestrians. Since the geometry of the ramp does not permit adequate sight distance for eastbound pedestrians to identify gaps in the traffic stream, a mirror has been provided.

Controls on Vehicle Movement

A traffic signal has been eliminated by bringing the St. Paul Street ramp terminal into the St. Paul-Mount Royal intersection. Since the intersection operates at capacity during peak hours, multiple phasing (e.g., to allow left turns) is not possible. Vehicle flow from the ramp should benefit from additional green time, but at the expense of increased merging conflicts past the intersection. Although left-turns from the ramp and right-turns from St. Paul could not be allowed, these movements are not presently permitted.

The heavy peak hour traffic volumes found on the Mount Royal ramp prohibited the use of a restrictive traffic control device. Consequently, the free flow characteristics of the ramp were retained.

Discussion

This illustrative design is heavily oriented toward the individual problems of this particular interchange. If the vehicular capacity problems had not been present and if pedestrian volumes had been greater, the uncontrolled Mount Royal ramp could have been brought under signal control, thus removing all points of pedestrian/vehicle conflict.

The choice of warning devices was essentially arbitrary; rumble strips or pavement markings could be either more or less effective than flashing lights. The selection of the mirror probably would necessitate some form of pedestrian education, perhaps by the use of informational signs adjacent to the crosswalk.

3.2.2 North Charles at I-83

3.2.2.1 Description of the Interchange

This interchange is located immediately northwest of the location described in the preceding section (See Figure 1). The portion of the intechange which was chosen for analysis was the entry ramp from Charles Street onto northbound I-83.

Context

The Charles Street interchange serves a similar function to the St. Paul-Mount Royal facility, except that traffic is directed out of rather than into the Baltimore central area. Since North Charles Street is a major outbound artery, its heaviest volumes occur between 4:00 and 6:00 p.m.

The interchange is surrounded by several major land uses, all of which generate considerable pedestrian traffic across the North Charles Street on-ramp. To the north is the Pennsylvania Railroad Station and a neighborhood commerical district. To the south is the University of Baltimore, a housing complex for the elderly, and a major office-commercial complex along Mt. Royal Avenue.

The peripheral land uses create a condition of heavy pedestrian volumes along North Charles Street in the vicinity of the interchange on a continuous basis. This is principally due to the requirement of linkage of abutting land uses that have been disassociated by the location of the expressway.

Provisions for Vehicle Movement

North Charles Street is a four-lane, one-way northbound arterial; in the vicinity of the I-83 overpass, an additional lane is provided for vehicles turning left into the expressway on-ramp. The distance between traffic signals (one located at North Charles and Mt. Royal, 560 feet south of the free-flow ramp, and one located on North Charles adjacent to the access portal to Pennsylvania Station, 160 feet north of the ramp) provides more than 720 feet of uncontrolled vehicle movement along North Charles Street. Within this distance there are several merging conflicts created by the I-83 on-ramp, a one-way cross street feeding into North Charles 120 feet south of the ramp, and several parking lot exits within the right-hand lanes of North Charles Street. These situations impede traffic flow and vehicle movement onto the expressway. Vehicle movement patterns are illustrated in Figure 5. Volumes of 3200 VPH on North Charles Street and 1800 VPH on the free-flow entrance ramp were observed during the evening peak hours. The only control device provided within the environment of the interchange is a "YIELD TO PEDESTRIANS" sign directly north of the ramp terminal.

Provisions for Pedestrian Movement

There is a ten foot sidewalk along the east side of North Charles Street where Charles intersects I-83. Along the west side, the sidewalk width is restricted to five feet between the University of Baltimore and the ramp; north of the ramp the sidewalk returns to a width of ten feet. The sidewalk along the west side of North Charles Street continues along the street and turns down along the on-ramp for a distance of 45 feet where it then terminates in a pedestrian at-grade zebra crosswalk perpendicular to the ramp, connecting to the sidewalk on the opposite side of the ramp.

The majority of pedestrian traffic is generated by land use activities west of North Charles Street. Since there are no traffic signals in the vicinity of the interchange and because the vehicle flow and width of North Charles preclude pedestrians from crossing to use the east sidewalk, 85 percent of the pedestrian flow on the arterial occurs within the ramp environment rather than on the opposite side of the street where no pedestrian/vehicle conflict exists. Pedestrian volumes across the ramp of 120-150 persons/hour were observed.

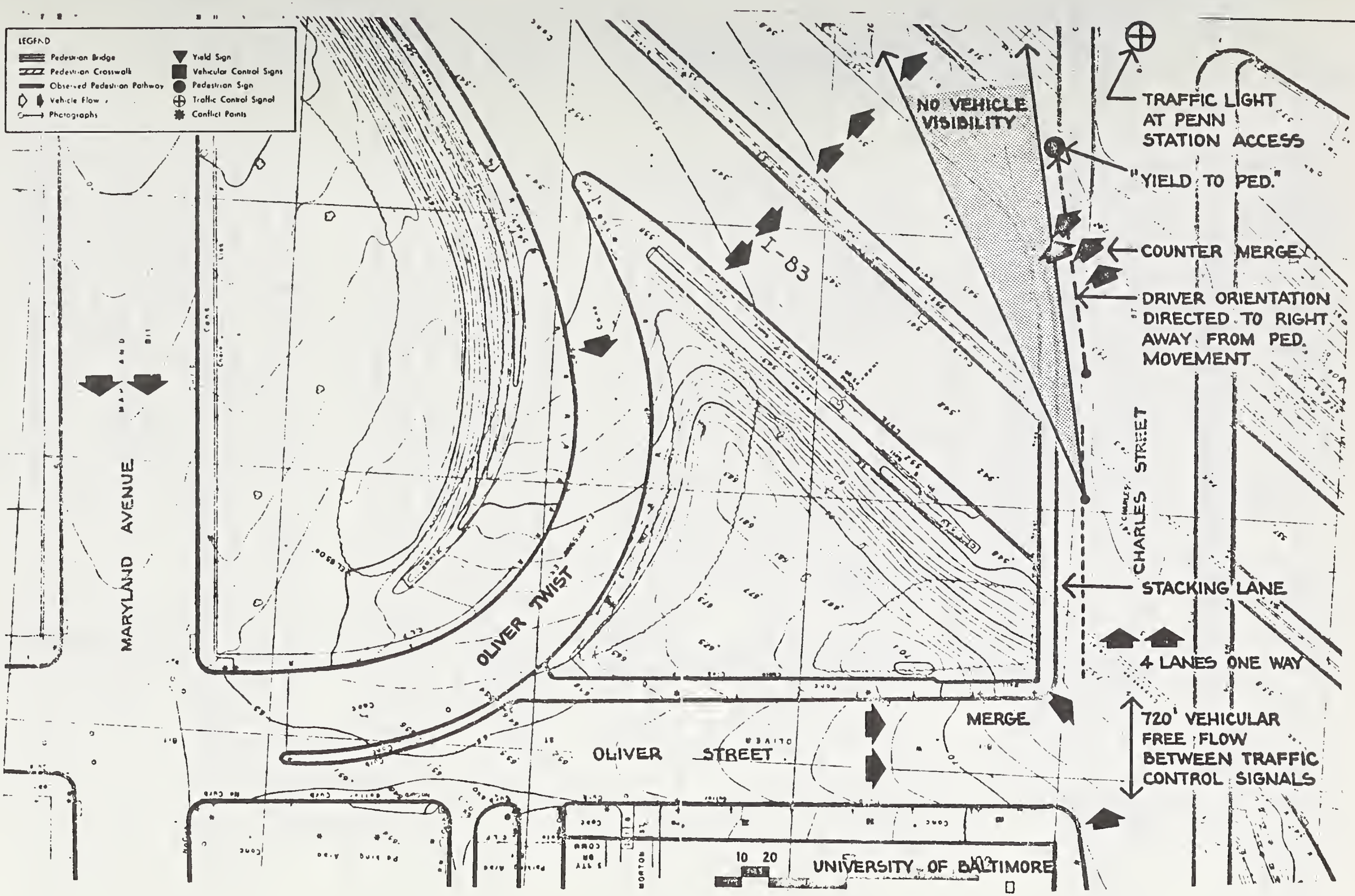


Figure 5. Vehicle movement -- Charles St./I-83

In terms of actual utilization of the crosswalk provision, approximately 30 percent of the pedestrians moved down the ramp to use the walk; the remainder chose to take the direct path across the ramp.

Pedestrian/Vehicle Conflict Points

The major conflict points occur in the marked crosswalk on the entry ramp and along the ramp apron where pedestrians who continue walking in a straight line traverse the roadway. Other conflict points in the general area of the interchange are indicated on Figure 6.

3.2.2.2 Effectiveness of the Interchange Components

Pedestrian/Driver Awareness

Pedestrians who use the marked crosswalk to traverse the ramp are not visible to approaching motorists. The physical geometry of the roadway and the placement of the crosswalk result in a crossing location which is lower in elevation and obscured by structural elements of the bridge. The placement of the "YIELD TO PEDESTRIANS" sign on the drivers' right can divert attention away from pedestrian movement on the left. The presence of the crosswalk may in itself engender a false sense of security in pedestrians, who may not be aware that vehicles may be physically unable to yield to them. However, since the crosswalk is perpendicular to the roadway, vehicle movement in the immediate vicinity of the crossing point is within the pedestrians' field of vision.

Those pedestrians who choose to disregard the crosswalk by continuing directly across the ramp in line with the sidewalk are more visible to approaching drivers. However, drivers may not expect pedestrians to cross at this point and, as mentioned previously, drivers may be distracted by the pedestrian warning sign. In addition, northbound pedestrians must look behind them to see oncoming traffic, thereby increasing the potential for pedestrian unawareness of vehicle flow.

Another awareness problem common to both crossing locations occurs during peak hours. Since the ramp is wide, two lanes of vehicular traffic may occasionally be formed. It was observed that when the left turn lane feeding into the entrance ramp was saturated and vehicles were moving at 3-5 mph, other vehicles would turn directly into the ramp from the next lane, bypassing the queue, and accelerate on the ramp apron to facilitate access to the expressway. This vehicle movement can result in a "multiple threat" conflict situation for pedestrians who attempt to cross between the slowed vehicles and are not aware of the additional hazard of faster vehicles.

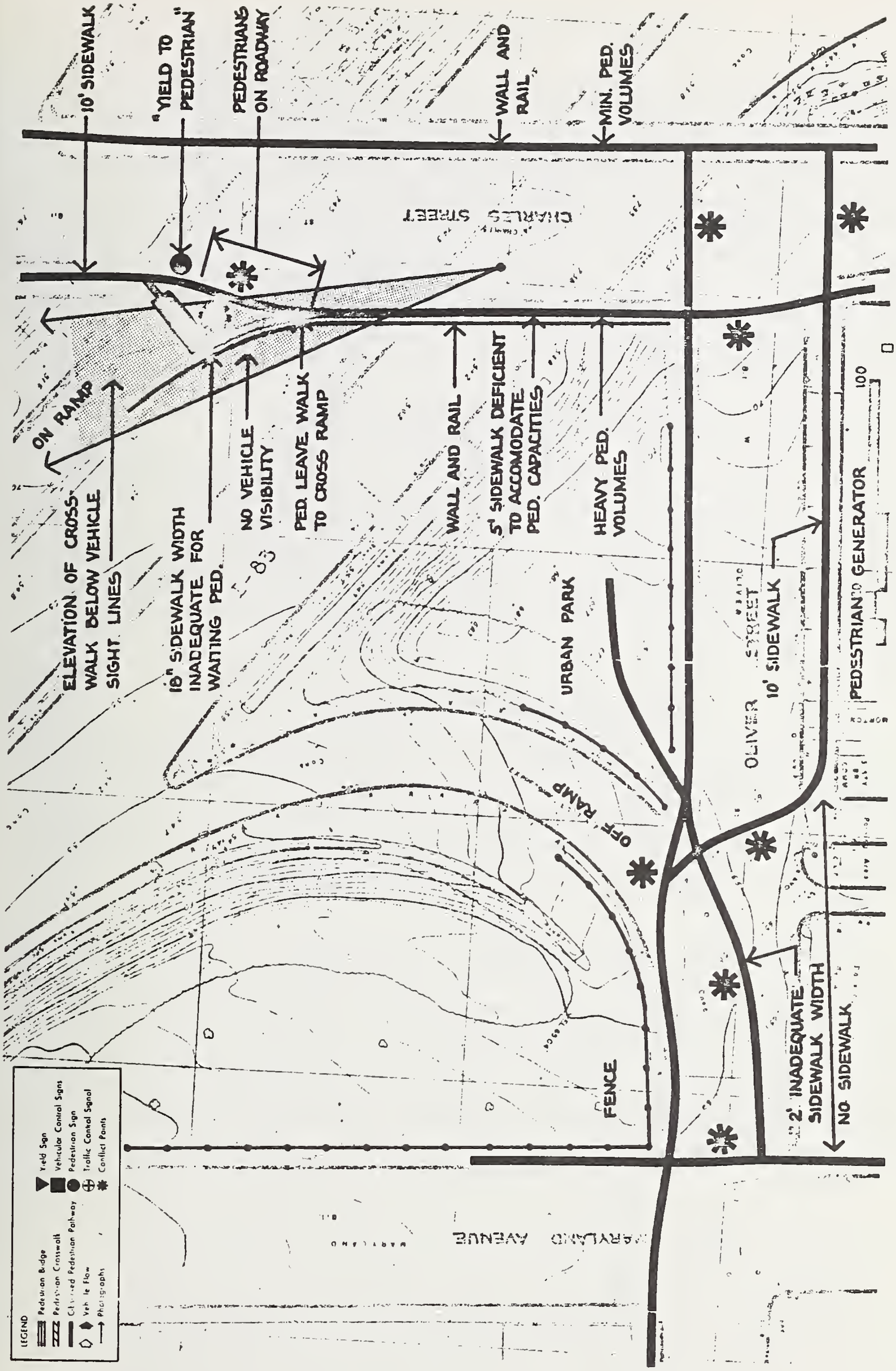


Figure 6. Pedestrian movement - Charles St./I-83

Controls on Pedestrian Movement

The prescribed pedestrian pathway discourages utilization because it is not direct; pedestrians must travel an additional 45 feet on the west side of the ramp in order to make use of the crosswalk. However, the crosswalk minimizes pedestrian exposure to vehicles because it is perpendicular to the roadway; pedestrians who disregard the provision must travel almost twice as long on the ramp. The sidewalk leading to the crosswalk, which is reduced to a width of 18 inches at the point of crossing, does not have suficient capacity to accommodate the pedestrians waiting for gaps in the vehicular traffic stream, thereby encouraging pedestrians to take risks by standing in the roadway or accepting smaller gaps.

3.2.2.3 Illustrative Design Improvements

This example is oriented toward the provision of a pedestrian crossing which would maximize the awareness of drivers and pedestrians. The overall design is displayed in Figure 7; a typical section is illustrated in Figure 8. Since the ramp crossing improvements would only be effective if the crosswalk is utilized, pedestrian movement is controlled by the use of countermeasures. The impacts of the improvements on vehicle flow should be minimal.

Pedestrian/Vehicle Awareness

This configuration substantially increases drivers' awareness of pedestrian movement at the Charles Street on-ramp. Pedestrian movement across the ramp is limited to a highly visible location. The battery of warning devices should make drivers expect the presence of pedestrians. Since merging conflicts occur upstream of the crosswalk, drivers can focus on the identification of pedestrians.

At the same time, pedestrians are more aware of vehicle movement. The location of the crosswalk provides an excellent field of vision; this is reinforced by the perpendicular placement of the walk which insures that crossing pedestrians will continue to be alert to approaching vehicles. Because ramp traffic is restricted to one lane, the possibility of multiple threat conflicts is eliminated. Also, the potential for crosswalk accidents caused by "last minute" vehicle turns into the ramp is reduced.

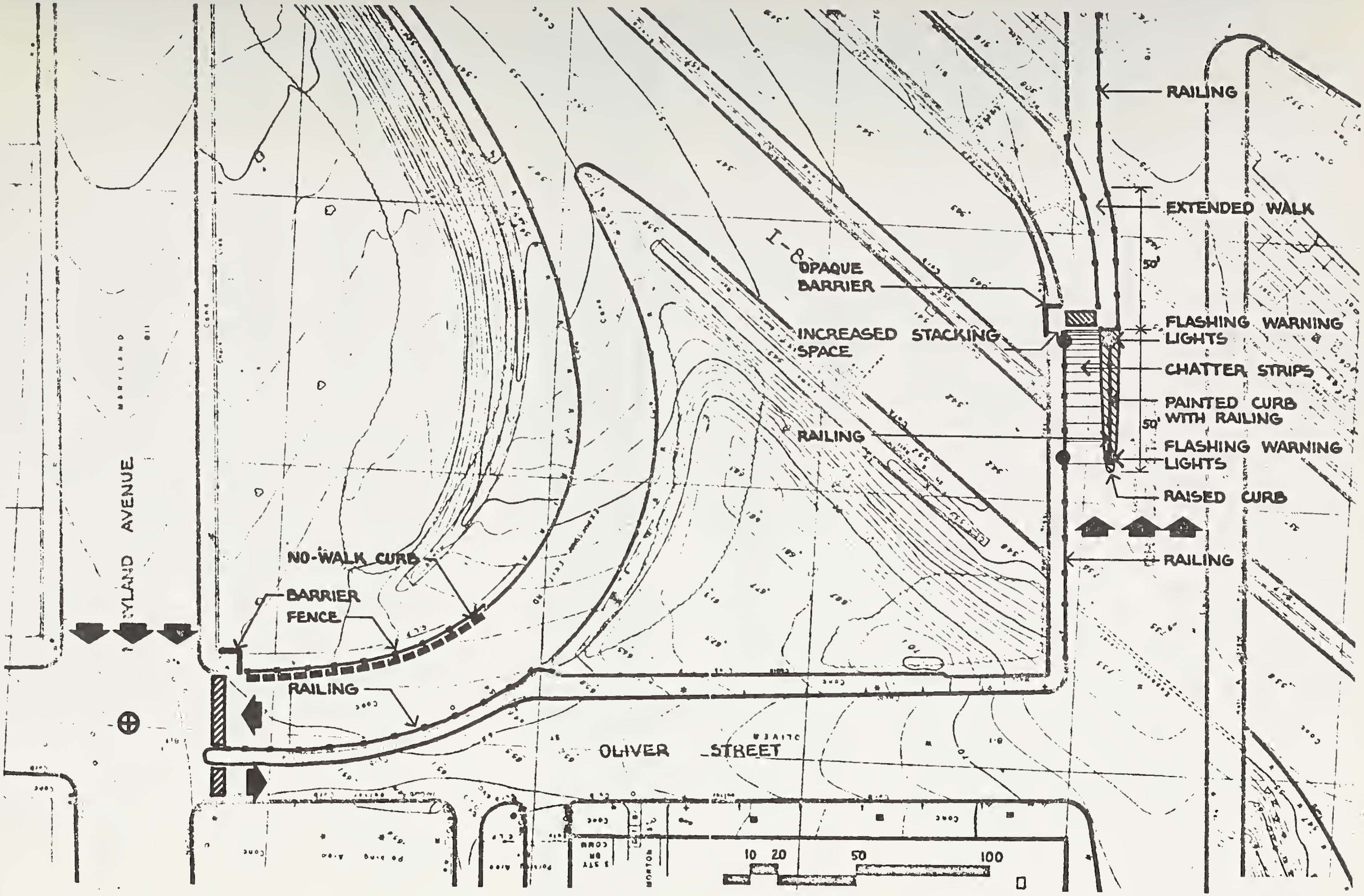


Figure 7. Suggested improvements - Charles St./I-83

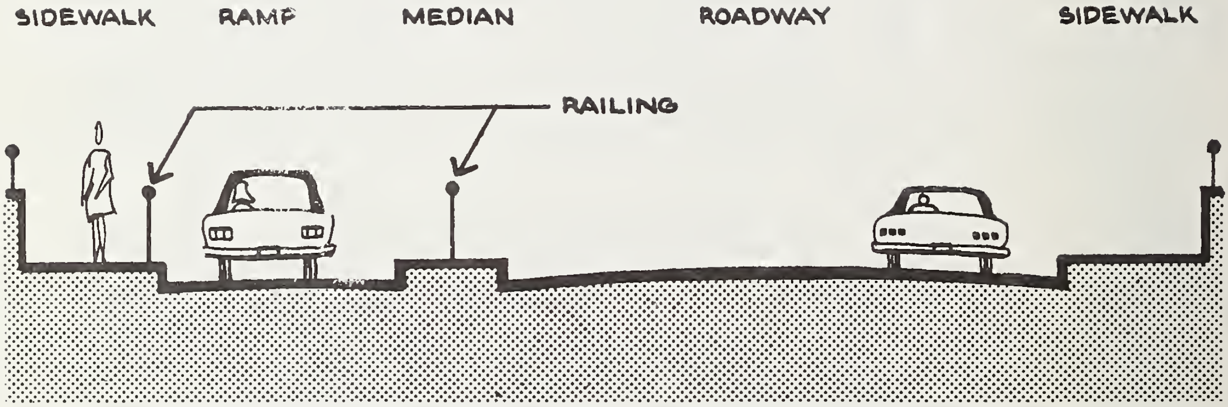


Figure 8. Charles St. ramp section

Controls on Pedestrian Movement

The careful provision of fencing has been used to control pedestrian movement. In this instance, the countermeasure increases the path distance only slightly while forcing pedestrians to use the crosswalk. The fencing on the ramp nose and the outside of the path north and south of the crosswalk is needed to discourage pedestrians from using the extended sidewalk channel as a safety island to facilitate crossing Charles Street.

Controls on Vehicle Movement

The increased channelization forces drivers to merge well before the pedestrian crossing and eliminates the possibility of turning illegally from the adjacent lane directly into the ramp. The additional pedestrian-related warning devices may also encourage more cautious driver behavior.

Discussion

Although traffic signals could be used to provide safe crossing opportunities for pedestrians, the light pedestrian volumes and heavy vehicle flows mitigate against this option.

3.2.3 Liberty Road at I-695

3.2.3.1 Description of the Interchange

This interchange is part of the Baltimore beltway and is located five miles north of the city limits.

Context

The arterial routes which the beltway intersects are typically radial, connecting the beltway and surrounding surburban areas with the central city. Liberty Road is one of five such arteries which serve the northwest Baltimore metropolitan region.

The I-695/Liberty Road interchange is surrounded by residential neighborhoods, suburban in character, although areas of neighborhood commerical activity and school facilities exist within walking distance of the interchange.

No primary pedestrian generators exist within the immediate vicinity of the interchange. Being surrounded by almost exclusively single-family detached housing, the only pedestrian traffic across the interchange is that of area residents walking to other families within the neighborhood, and some shopping trips to neighborhood commercial facilities on the opposite side of the expressway.

Provisions for Vehicle Movement

This interchange is a typical cloverleaf as indicated in Figures 9 and 10. Liberty Road is two lanes in each direction with a concrete median strip separating each roadway. Additional width occurs on Liberty Road beneath the I-695 overpass for acceleration/deceleration and merging. This additional width is lacking, however, from the approaches to and from the ramps which are not beneath the overpass. For both I-695 and Liberty Road, all exits and entrances are made from the drivers right.

Service streets parallel Liberty Road on the south side of the roadway on either side of the beltway. No direct access is possible from these service streets to the ramps of the interchange, although there exists only a short distance between ramp and street. The service streets are separated from Liberty Road by narrow concrete median strips with access being provided by the nearest intersection in the case of the service street in the southwest quadrant of the interchange, and by a cut through the concrete median in the case of the service street in the southeast quadrant. This latter service street terminates as it approaches the interchange ramp, while the service street in the southwest quadrant does not terminate, but rather makes a right angle turn away from Liberty Road towards the south, and continues as part of the residential street network.

One factor which impacts the flow and movement patterns of vehicular traffic through the interchange is the presence of a traffic light on Liberty Road, approximately 1000 feet to the west of the expressway overpass at the first street to intersect Liberty Road. This light causes "platooning" or bunching of vehicular traffic on eastbound Liberty Road and periodic back-ups of traffic within the interchange for westbound traffic awaiting a green light at this point. The relatively short distance between the beltway off- and on-ramps underneath the overpass creates complicated weaving maneuvers, especially during peak traffic periods, when traffic backs up on the freeway ramps. Peak hour traffic volumes on the various ramps range from 200 VPH to over 900 VPH. During the offpeak hours, however, traffic typically flows freely through the interchange.

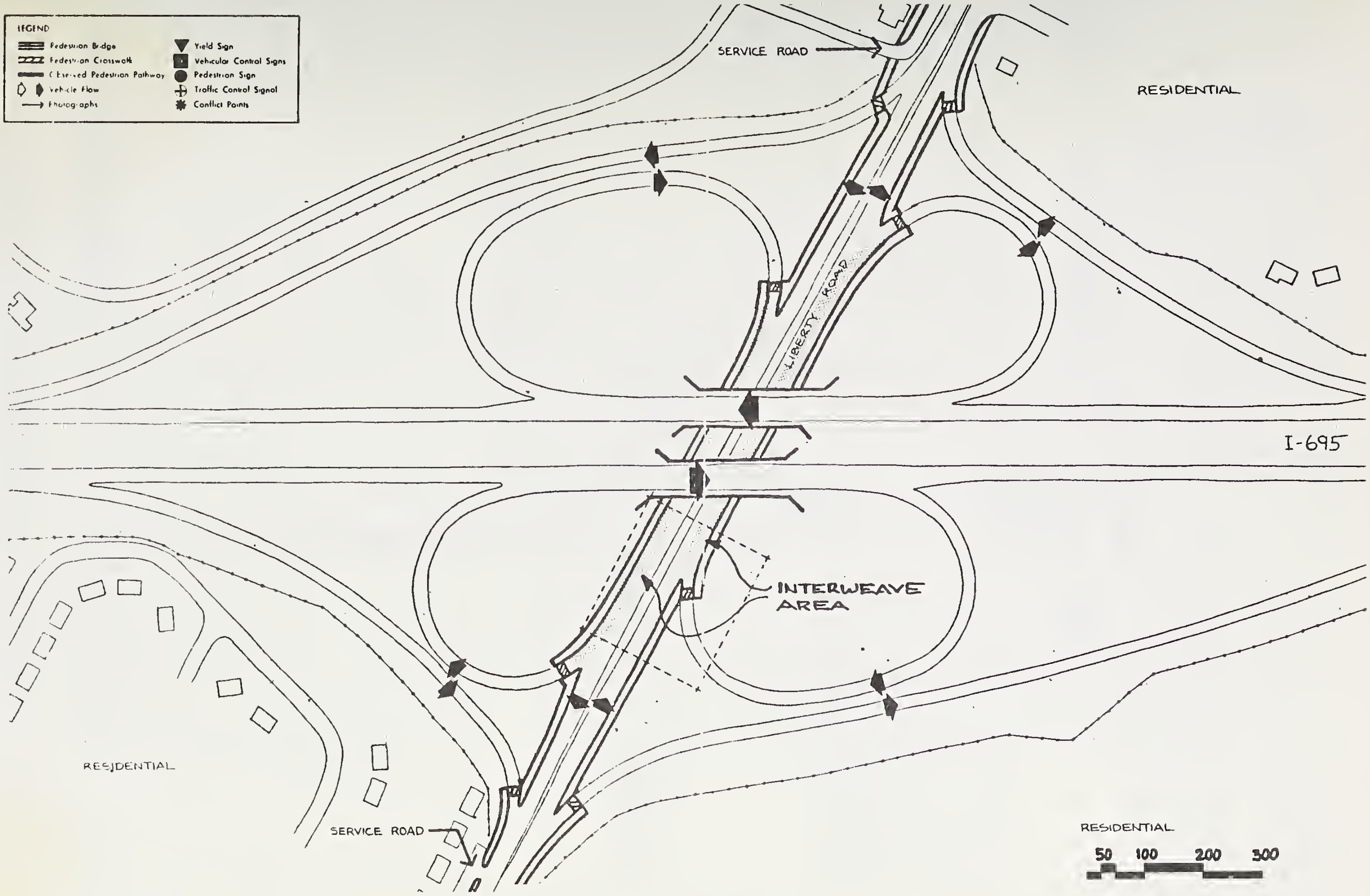


Figure 9. Vehicle movement - Liberty Road/I-695.

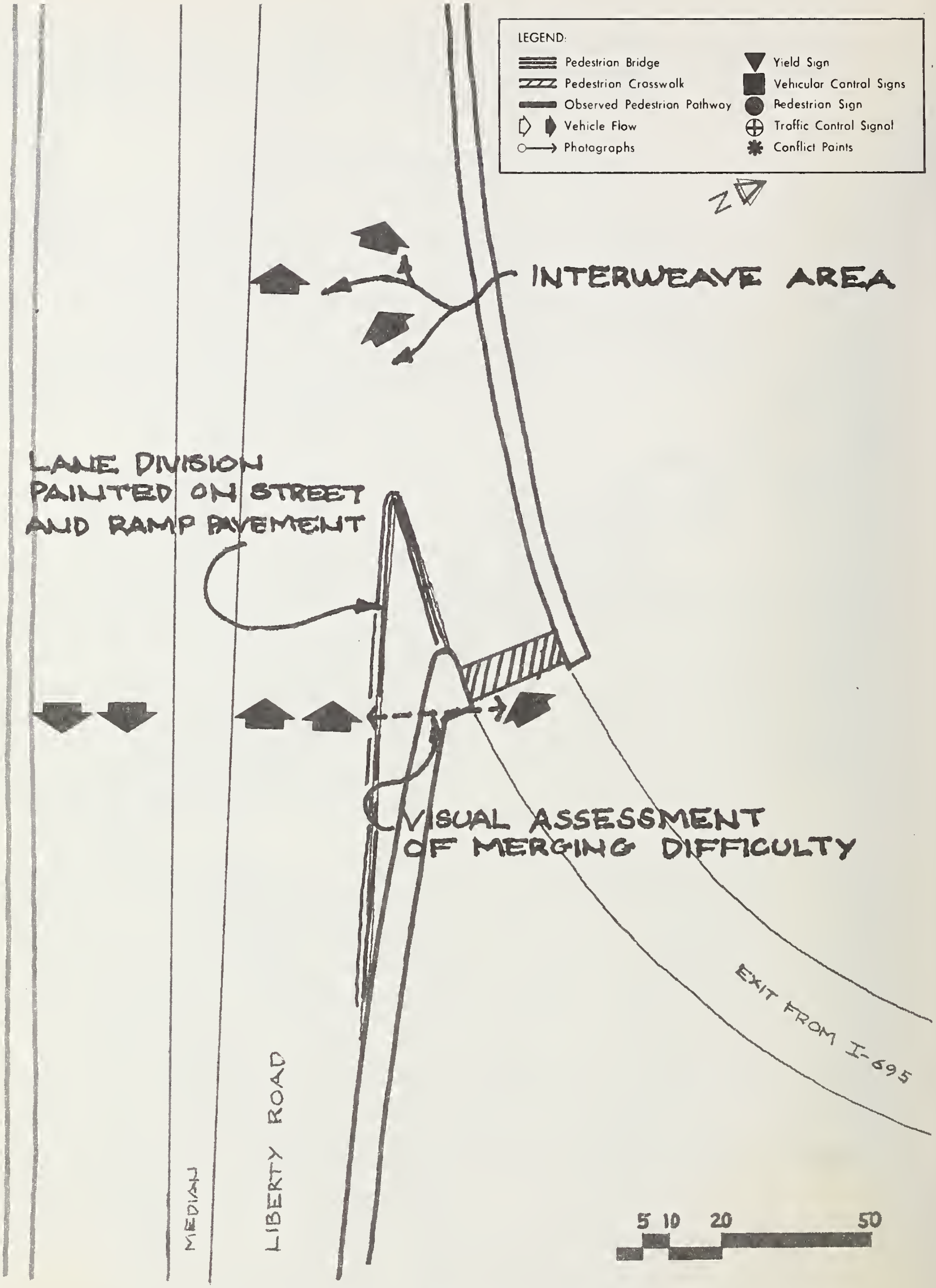


Figure 10. Vehicle movement at ramp terminal.

No controls exist at this interchange which restrict vehicular movement relative to pedestrian needs. However, an unusual sign has been used to increase driver awareness of the presence of pedestrians crossing ramps. This sign consists of a silhouette symbol of pedestrians within a crosswalk, with another sign placed immediately beneath this with the words, "ACROSS RAMPS". These two signs are approximately equal in size and are immediately touching, forming one sign element. This device is placed in four locations, on each of the beltway exit ramps, approximately 100 feet before the crosswalk.

Provisions for Pedestrian Movement

Pedestrian accommodations for this interchange, as is often the case with interchanges of this configuration, are minimal, consisting only of sidewalks on each side of Liberty Road and painted crosswalks where these sidewalks intersect the ends of exit and entrance ramps. These accommodations are shown on Figures 11 and 12. Of note is the path of the sidewalk as it approaches each ramp end. In each case the walk follows the ramp as it curves away from Liberty Road, extending along the ramp for a distance of 40 to 50 feet. At this point, the sidewalk terminates and the pedestrian is directed to cross the ramp at a right angle.

The service streets on the south side of Liberty Road have their own sidewalks. In the case of the service street in the southeast quadrant of the interchange, sidewalk paving exists at both the service street and the median strip separating the service street from Liberty Road. In the case of the southwest quadrant, a crosswalk has been installed which directs pedestrians away from Liberty Road, across the service street and to the service street sidewalk.

The beltway is a major freeway which, due to its physical embankments and right-of-way fencing, virtually prevents incursion by pedestrians. The only possible crossing points occur at the interchange, for which accommodations are provided. Movement patterns adhere to the alignment of the sidewalks, but not to the crosswalks at free-flow ramp terminals. Because of the perceived inconvenience of following the prescribed path, most pedestrians continue across the ramp in almost a direct line with the sidewalk, with only a slight deviation toward the intended crosswalk route. The observed volume of pedestrian traffic through the interchange was very light. However, this traffic is consistently present during the day and early evening hours.

Pedestrian movement along the service streets in the southwest quadrant was observed to adhere to the provided sidewalk. The short

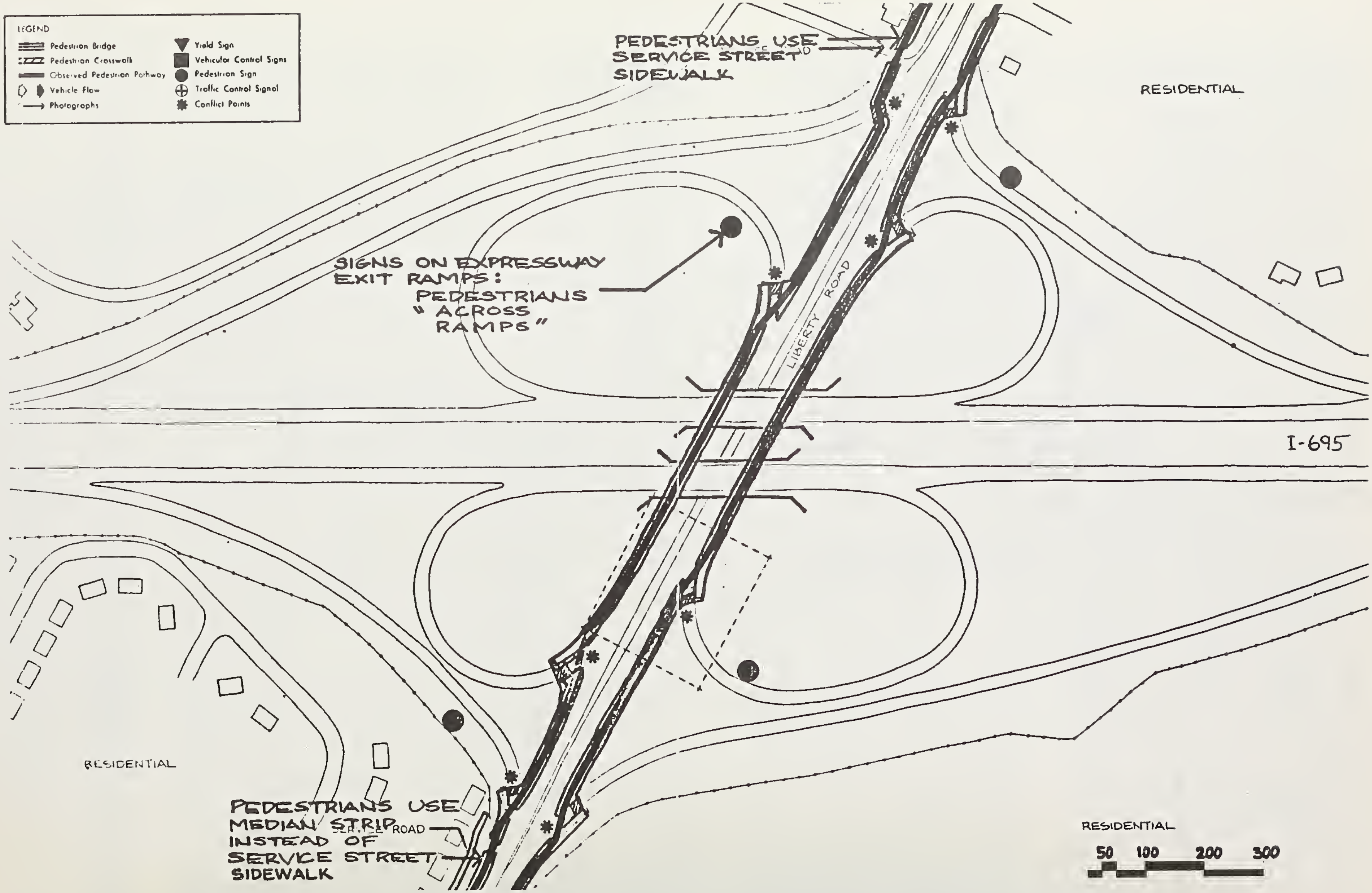


Figure 11. Pedestrian movement - Liberty Road/I-695.

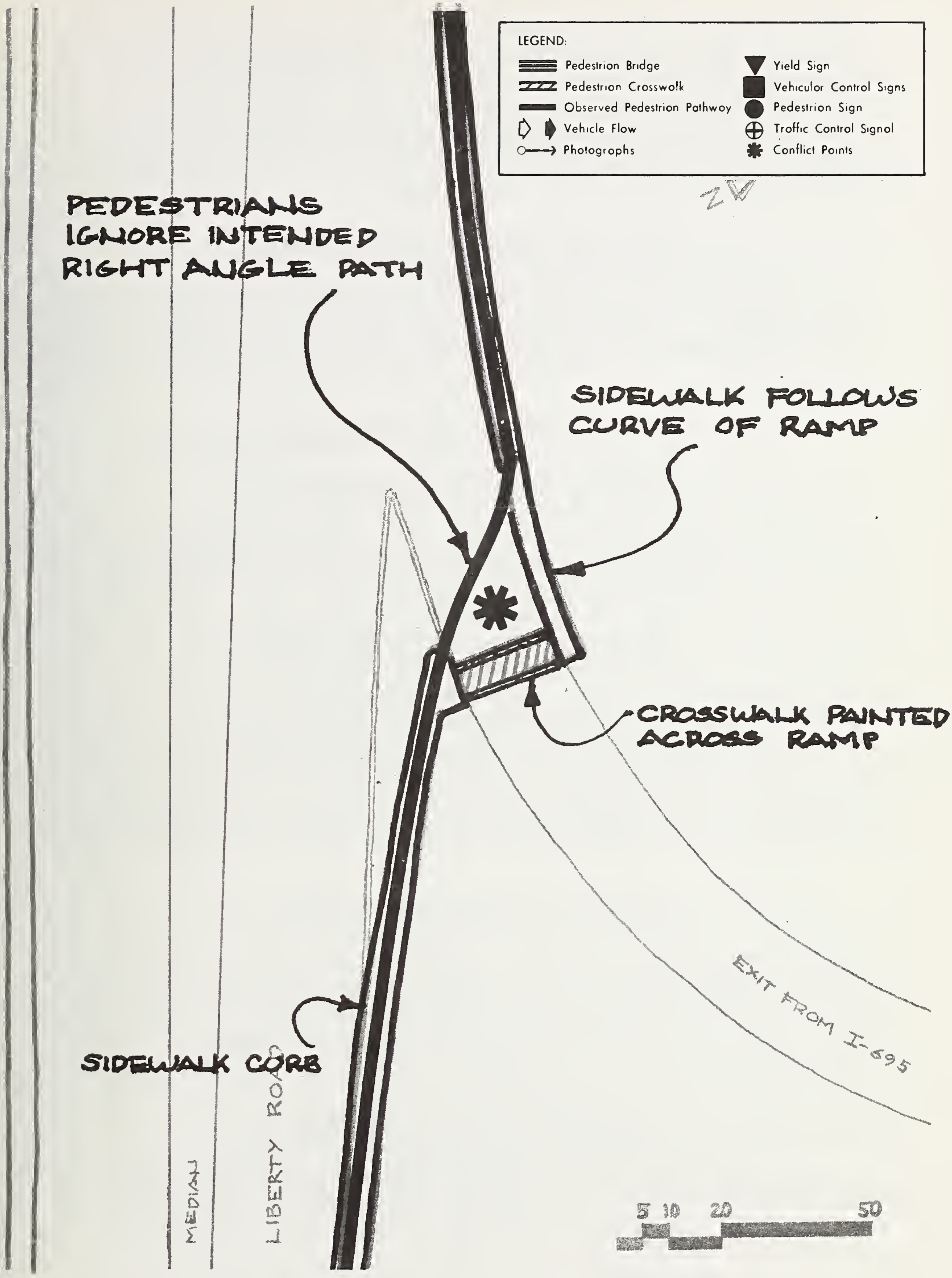


Figure 12. Pedestrian movement at ramp terminal.

walk between the service street and the Liberty Road sidewalk through the interchange is used, with little or no pedestrian movement occuring on the dividing strip between the avenue and the service street. In the southest quadrant, however, no provision exists to direct pedestrian traffic from the interchange sidewalk to the service street sidewalk; therefore, pedestrians continue along the divider strip separating the service street from Liberty Road.

Pedestrian/Vehicle Conflict Points

The points of pedestrian/vehicular conflict are indicated on Figures 11 and 12. A pedestrian who traverses the interchange is subjected to a minimum of four separate uncontrolled roadway crossings.

3.2.3.2 Effectiveness of the Interchange Components

Pedestrian/Driver Awareness

Although there are no significant physical obstructions to restrict visibility, the geometry of the interchange imposes limitations on the mutual awareness of drivers and pedestrians. The configuration of the off ramps results in a serious visibility problem. Drivers, concerned with the impending merge, focus their attention on the vehicular traffic on the arterial; pedestrian movement across the ramp may well be outside the driver's field of vision. This problem is intensified in cases where pedestrians, moving in the same direction as the vehicles, deviate from the crosswalk by moving directly across the ramp with their backs to vehicular traffic. Although standard highway lighting fixtures have been provided at the interchange, the illumination system was not designed to facilitate driver identification of pedestrians.

The provision of the aforementaoned warning signs on the exit ramps appears to have produced mixed results. Some drivers were observed to actually stop in order to give waiting pedestrians the opportunity to cross. The innovative design of the warning sign may have confused or intimidated drivers, resulting in relatively conservative driver behavior. However, many drivers did not appear to respond to the sign.

Controls on Pedestrian Movement

The intended pedestrian routes through the interchange generally conform to the travel desire lines. The pathway treatment at the ramp terminals, however, results in less pedestrian exposure to vehicle flow at the expense of path directness. This penalty in convenience, coupled with the absence of countermeasures, results in pedestrian disregard of the planned facilities. The configuration of the pathway forces pedestrians who are waiting to cross the ramp to stand at the unprotected nose of the ramp, where they are extremely vulnerable to vehicles.

The heavy volumes and high speeds of traffic complicate the actual ramp crossings. The traffic signal located west of the interchange causes platooning of eastbound arterial traffic and, during the peak period, backups on the westbound arterial. The resulting queues which are formed on the ramps allow pedestrians to cross between the stopped vehicles, but only at substantial hazard.

Controls on Vehicle Movement

The only pedestrian-related control that affects vehicular movement is the warning sign, which impedes vehicles significantly only when pedestrians are present. Most impedances in the interchange are caused by vehicular traffic considerations (e.g., merging, traffic signals).

3.2.3.3 Illustrative Design Improvements

An improved strategy for pedestrian accommodation at this interchange is illustrated in Figure 13. This design completely eliminates the pedestrian/vehicle conflict problem by providing spatially separate accommodations for pedestrian movement and deterring incursion into areas of vehicle traffic. However, this strategy can adversely affect traffic flow under certain conditions. Because this design removes all conflict points, awareness is not a major factor.

Controls on Pedestrian Movement

The placement of the pedestrian pathway in the median of the arterial eliminates the eight conflict points at the ramp terminals. Because the sidewalks along the outside of the arterial roadways are no longer necessary, the amount of space devoted to pedestrian movement has not been increased; see Figure 14. Pedestrian access to the pathway can be achieved by extending the walk to the nearest signalized intersection or by installing an additional traffic signal, either pedestrian activiated or coordinated, at an appropriate location. Although the directness of the pathway should discourage deviation from the walk itself, effective pedestrian barriers must be employed to restrict movement at the crossing; see Figure 15.

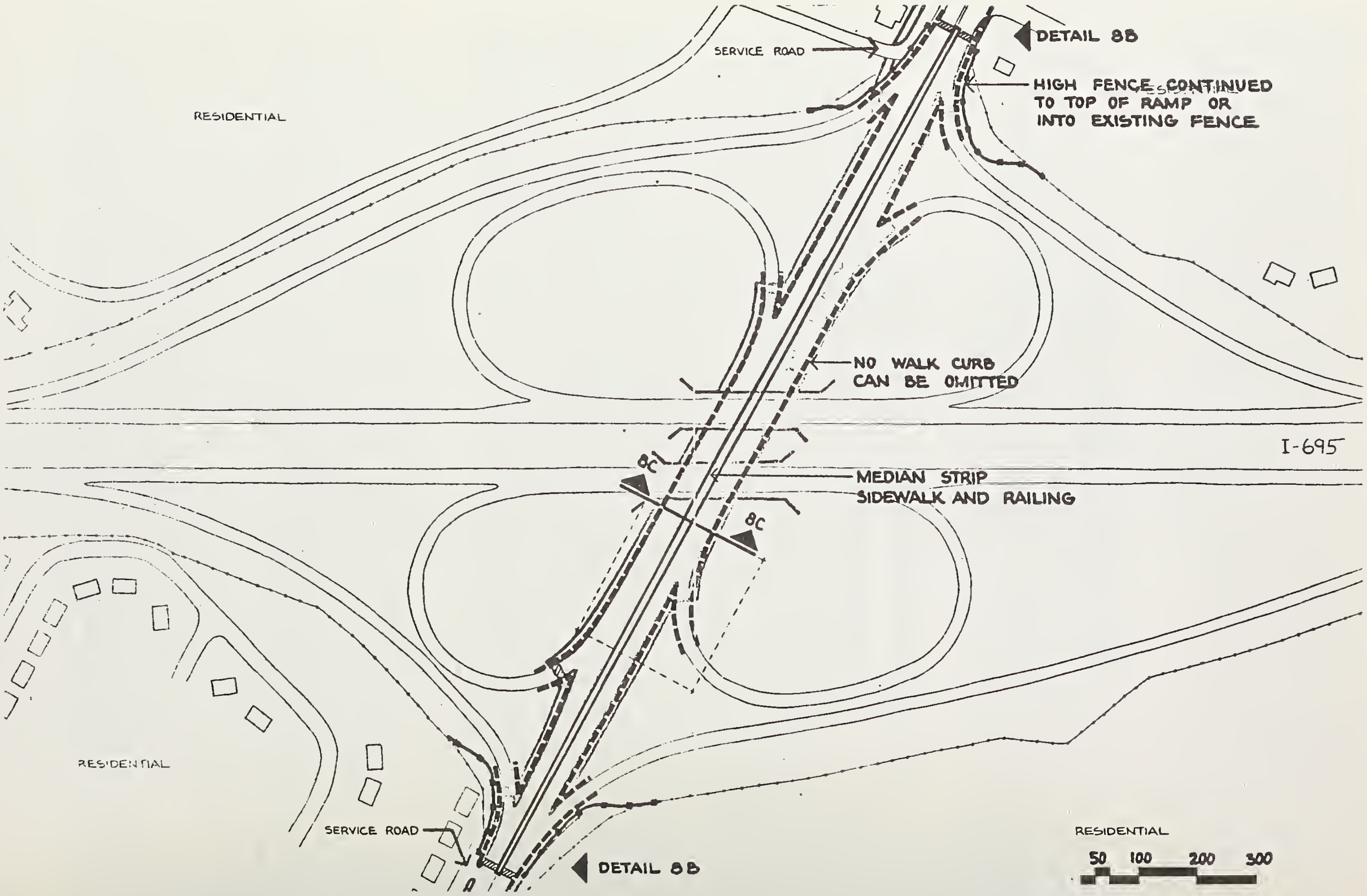

DETAIL 8B
SERVICE ROAD
HIGH FENCE CONTINUED TO TOP OF RAMP OR INTO EXISTING FENCE
RESIDENTIAL
NO WALK CURB CAN BE OMITTED
I-695
8C
MEDIAN STRIP SIDEWALK AND RAILING
8C
RESIDENTIAL
SERVICE ROAD
DETAIL 8B
RESIDENTIAL
50 100 200 300

Figure 13. Suggested improvements - Liberty Road/I-695.

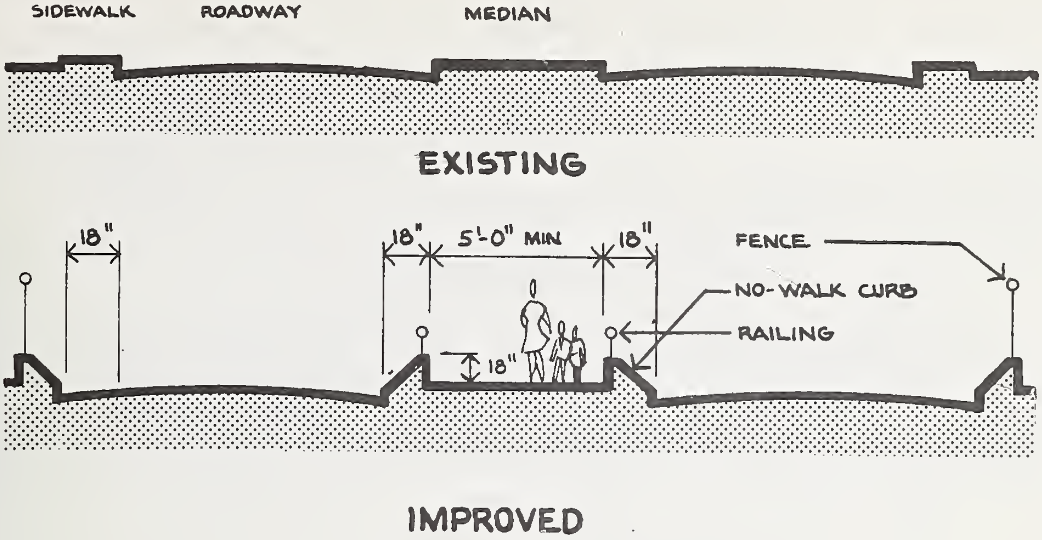


Figure 14. Liberty Road pathway sections.

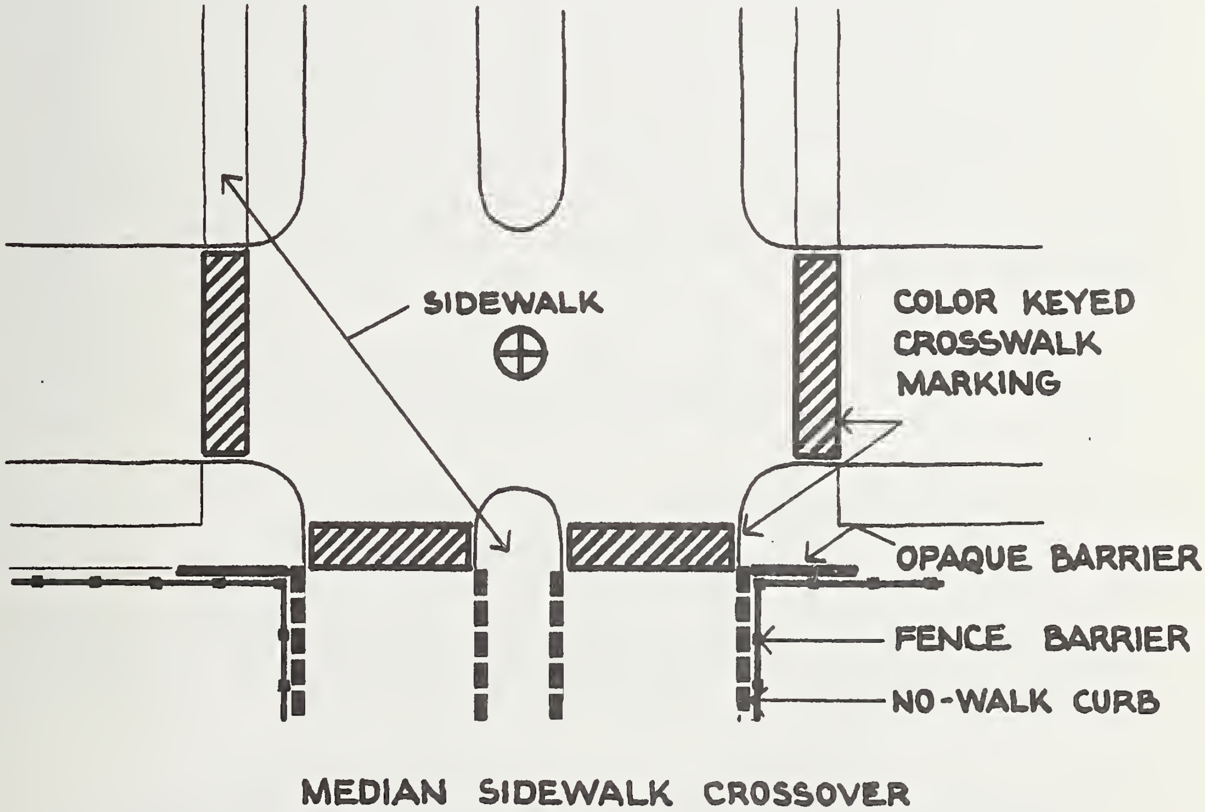


Figure 15. Liberty Road pathway terminal.

Vehicular Impacts

The removal of all pedestrian movement across the ramps should enhance vehicle flow through the interchange. However, if additional traffic signals on the crossroad are required to facilitate pedestrian access to the pathway, vehicle flow will be adversely affected.

Pedestrian/Driver Awareness

Since pedestrian movement has been spatially separated from vehicle traffic, the need for driver awareness of pedestrians has been removed. The innovatative nature of the design, however, necessitates pedestrian directional signing at the point where the median pathway begins.

Discussion

The problems identified at this location are typical of those found at most cloverleaf interchanges; the multiple pedestrian/vehicle conflict points are inherent in the basic design.

This design approach replaces a total of eight conflict points at the ramp terminals with four (potential) conflict points on the arterial crossroad. Since the conflicts on the arterial may be expected to be more severe due to the wider roadway and heavier traffic, signal control must be employed to facilitate pedestrian access to the median. The feasibility of the median pathway accommodation is therefore heavily dependent on the traffic and roadway characteristics of the individual situation (e.g., vehicle volumes, presence of a coordinated signal system).

A less extensive approach might be to simply restrict pedestrian movement across ramps to perpendicular crosswalks while employing warning devices to alert drivers to potential pedestrian movement.

3.2.4 28th Street at I-83

3.2.4.1 Description of the Interchange

This interchange, located in northern central Baltimore, provides access to I-83 from 28th Street, 29th Street, and Druid Hill Park Drive.

Context

The interchange is located approximately mid-way between downtown Baltimore and the suburban periphery to the north. As such, it serves as an access point to the transitional area between the high density commerically developed central city, and lower density residential areas. The interchange has a logical location as it is able to serve the 28th-29th Street arterial couple and Druid Hill Park Drive, a major thoroughfare to the west.

At the location of the interchange, I-83 is paralleled by the Penn Central Railroad which operates a large switching and freight handling yard at this point. Several industries have located next to the rail facilities to take advantage of freight handling capabilities. To the east of the interchange are medium density residential neighborhoods serving a middle to lower-middle income population; to the northwest of the interchange is Druid Hill Park, Baltimore's principal recreation facility which includes the city zoo; and to the southwest of the interchange is a residential area of medium density. Both the residential areas to the east and southwest have neighborhood commercial facilities and pockets of commercial and industrial activities relating to areas beyond the immediate neighborhoods.

The primary pedestrian generator for the area of the interchange is Druid Hill Park and the Baltimore Zoo. Of significance is the pedestrian travel desire between the residential area to the east and the park and zoo facilities to the west of the expressway. Following 28th and 29th Streets was, and still is, the only means in which this desire line for pedestrian travel is satisfied. The other major pedestrian generators are the railroad and industrial facilities located immediately to the east of the expressway. It was specifically for the needs of employees to be able to walk to these facilities from the residential areas on the west side of the expressway that the pedestrian bridges, ramps and sidewalks were incorporated into the design of the interchange when it was originally constructed in the early 1960's.

Provisions for Vehicle Movement

The configuration of the roadways and ramps is illustrated in Figures 16 and 17. The interchange is completely free-flow with no devices for the control of vehicular movement other than caution signs for the merging of traffic streams and directional signs. The expressway is depressed in a narrow valley with the crossing arterials originating from 70 feet above the expressway. In order to accomplish this change in elevation as well as avoid older established industrial facilities on the valley floor, the 29th Street ramp to northbound I-83 takes an unusually circuitous path. Of further note is that there is no direct access to southbound I-83 from eastbound 28th Street; this movement is accomplished at the next interchange to the south.

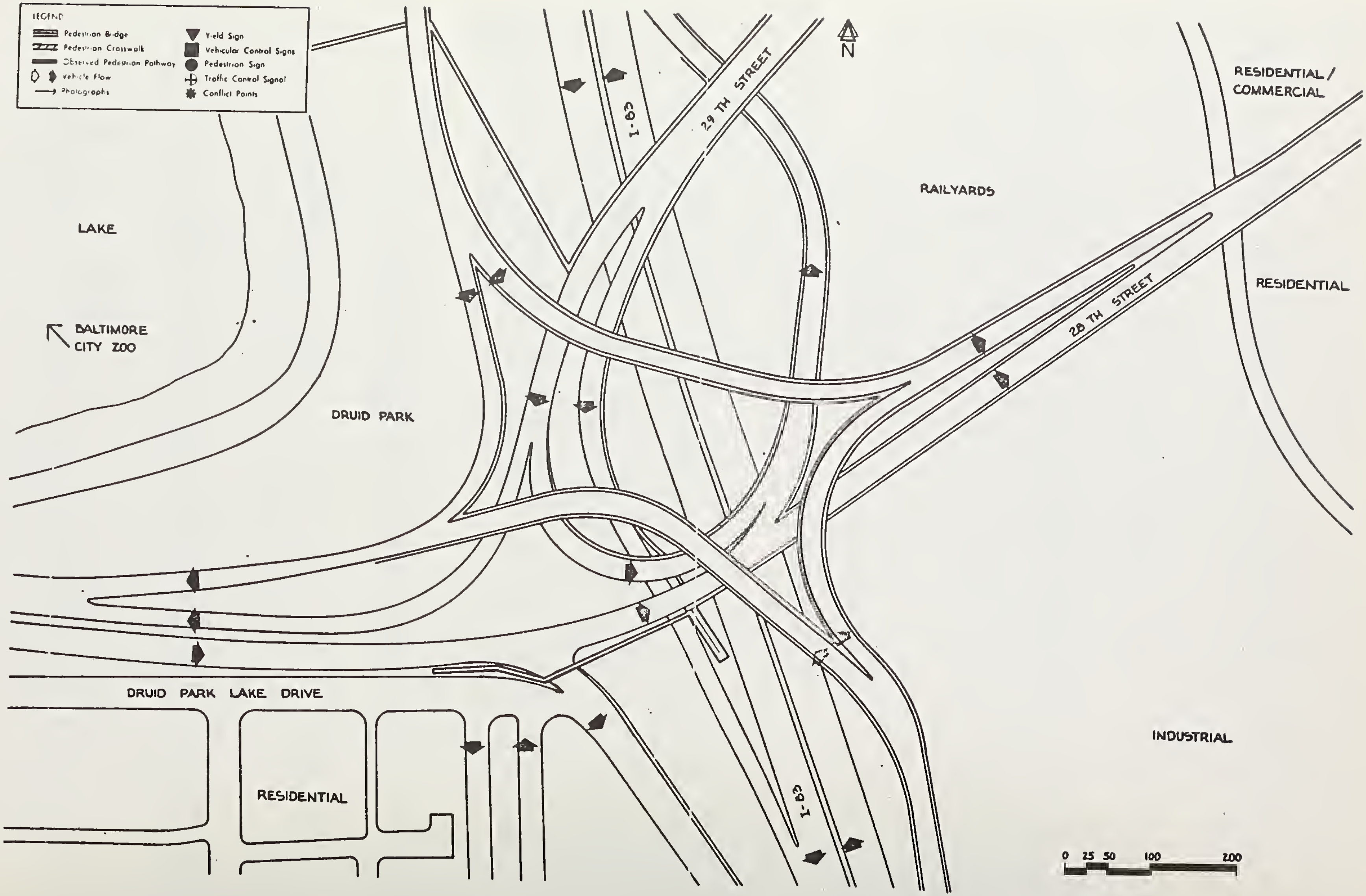


Figure 16. Vehicle movement - 28th St./I-83.

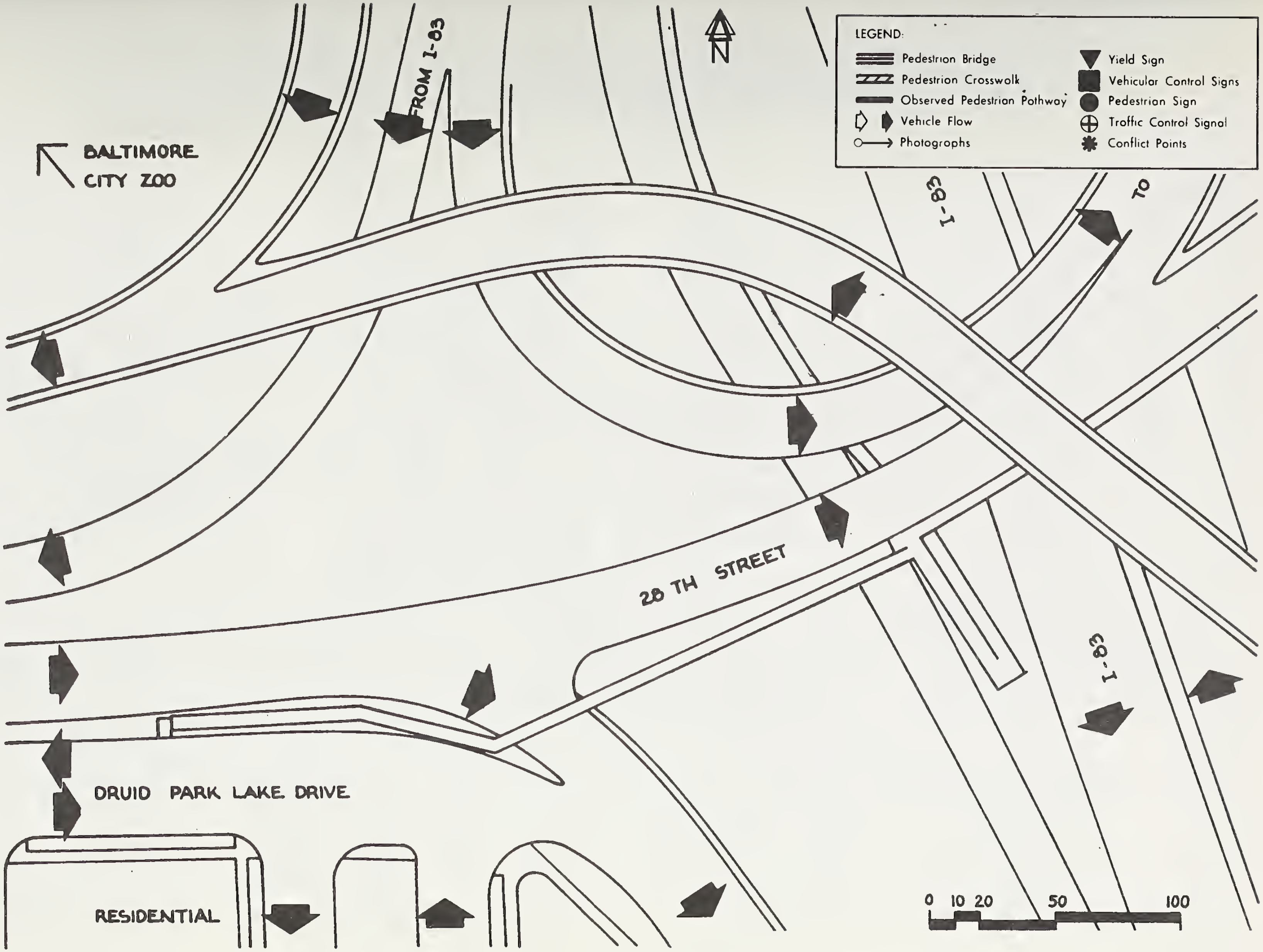


Figure 17. Vehicle movement at pedestrian bridge.

Although the interchange accommodates heavy traffic volumes, the high design standards result in consistently smooth vehicle flow with little evidence of congestion.

Provisions for Pedestrian Movement

The location and configuration of pedestrian accommodations is displayed in Figures 18 and 19. The accommodations are of two types: sidewalks and curbing of the roadways; and bridges and ramps designed specifically for pedestrian use. The physical design of the sidewalks is of standard detail with no barriers to confine movement to the walk, except for railings on the bridge and ramp structures. It should be noted that a wide bituminous curb, which was the appearance of a sidewalk, continues along the northern side of 29th Street. An unintended pedestrian path branches northwest from this bituminous curbing and converges with the northern 28th Street pathway at a ramp crosswalk leading to a set of stairs into Druid Hill Park. The southern 29th Street path and the southern 28th Street path converge at a "scissors" ramp which leads to a pedestrian bridge over a vehicle ramp adjacent to the residential area in the southwest quadrant. Aside from the physical design of the provided accommodations, the only additional devices to control pedestrian movement are signs which prohibit pedestrian access to the expressway itself.

Pedestrian movement conformed to the accommodations provided except for two instances; see Figures 20, 21, and 22. A number of alternatives existed to the use of the pedestrian bridge structure. Pedestrians were observed to move at street level across the service roads and free-flow right turnoff from eastbound 28th Street. The other principal deviation from the prescribed pathway consisted of pedestrian use of the bituminous curb leading along the north side of 29th Street and associated crossings of 28th and 29th Streets. Pedestrian volumes of 240 PPH were observed. Both the northern 28th Street sidewalk and the pedestrian bridge structure were observed to have light pedestrian flows.

Pedestrian/Vehicle Conflict Points

Only two points of pedestrian/vehicle conflict occur as a result of planned accommodations. The first is the surface crossing of the I-83 southbound exit ramp near Druid Hill Park. The second conflict point is at the western end of the bridge structure where pedestrians are directed to cross the service roadway. It should be noted, however, that in the latter case, vehicular traffic is very light and speeds are low. These and all other conflict points are indicated on Figures 20, 21, and 22.

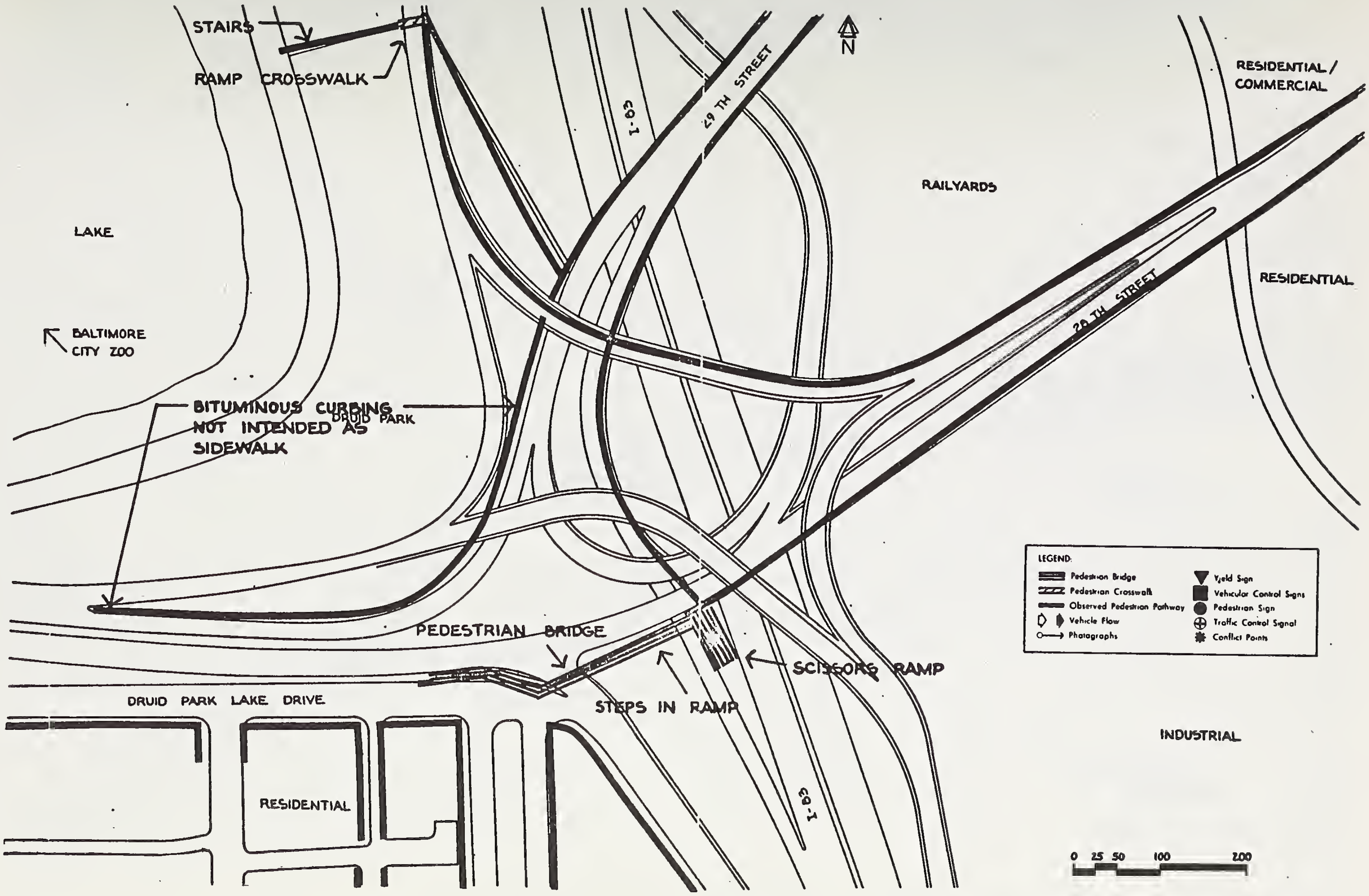


Figure 18. Pedestrian movement - 28th St./I-83.

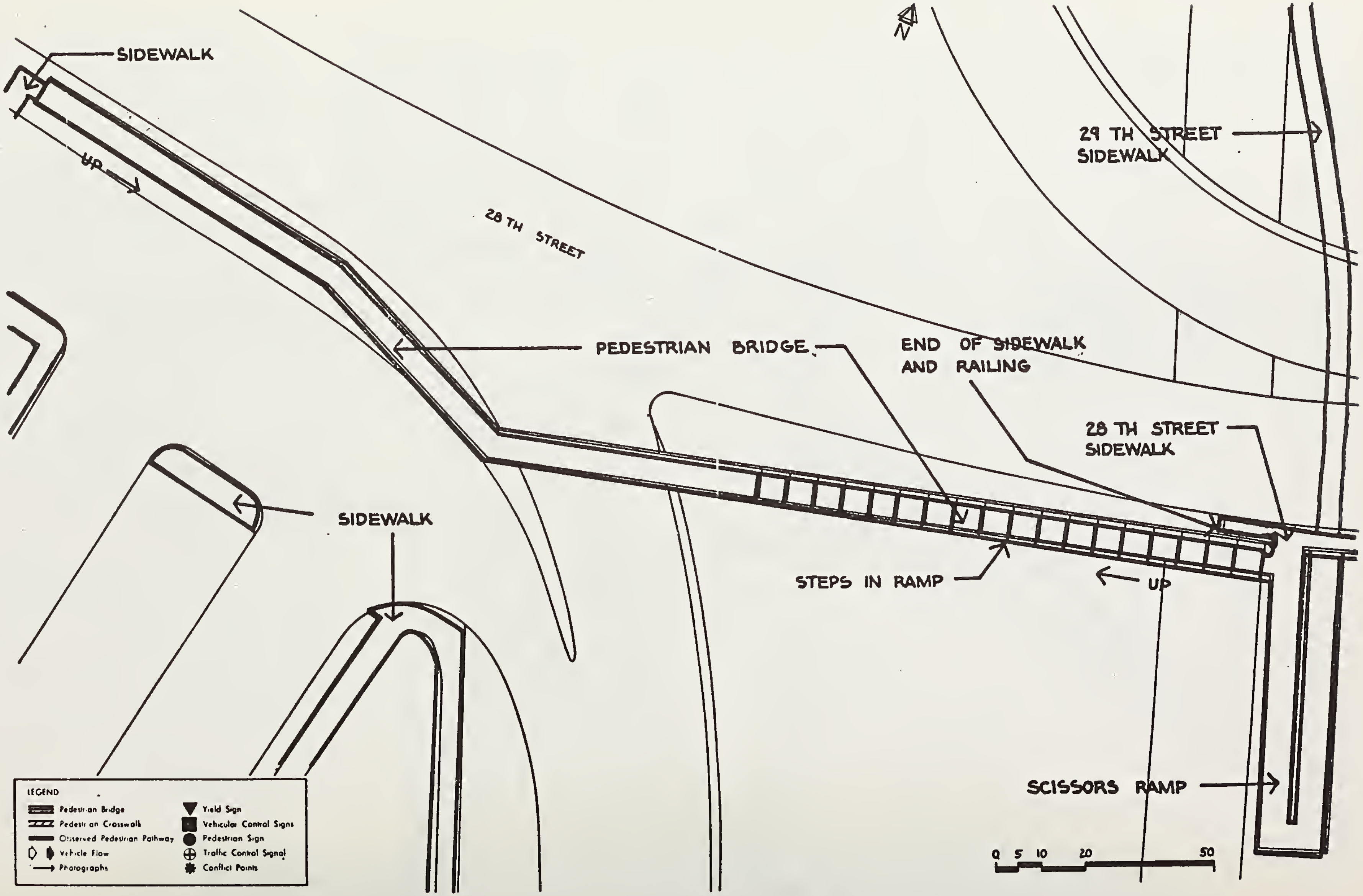


Figure 19. Pedestrian bridge and related accommodations.

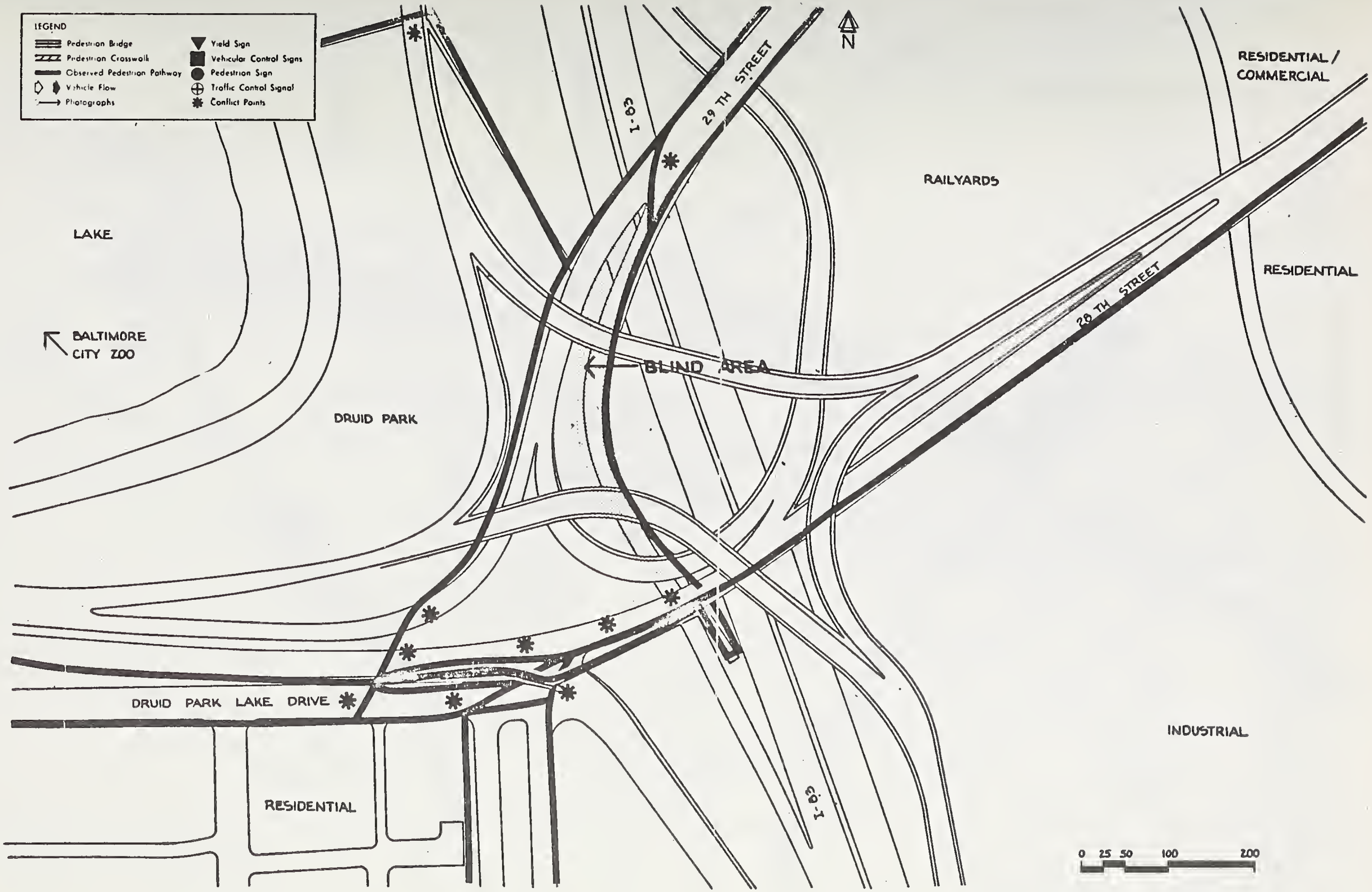


Figure 20. Pedestrian movement - 28th St./I-83.

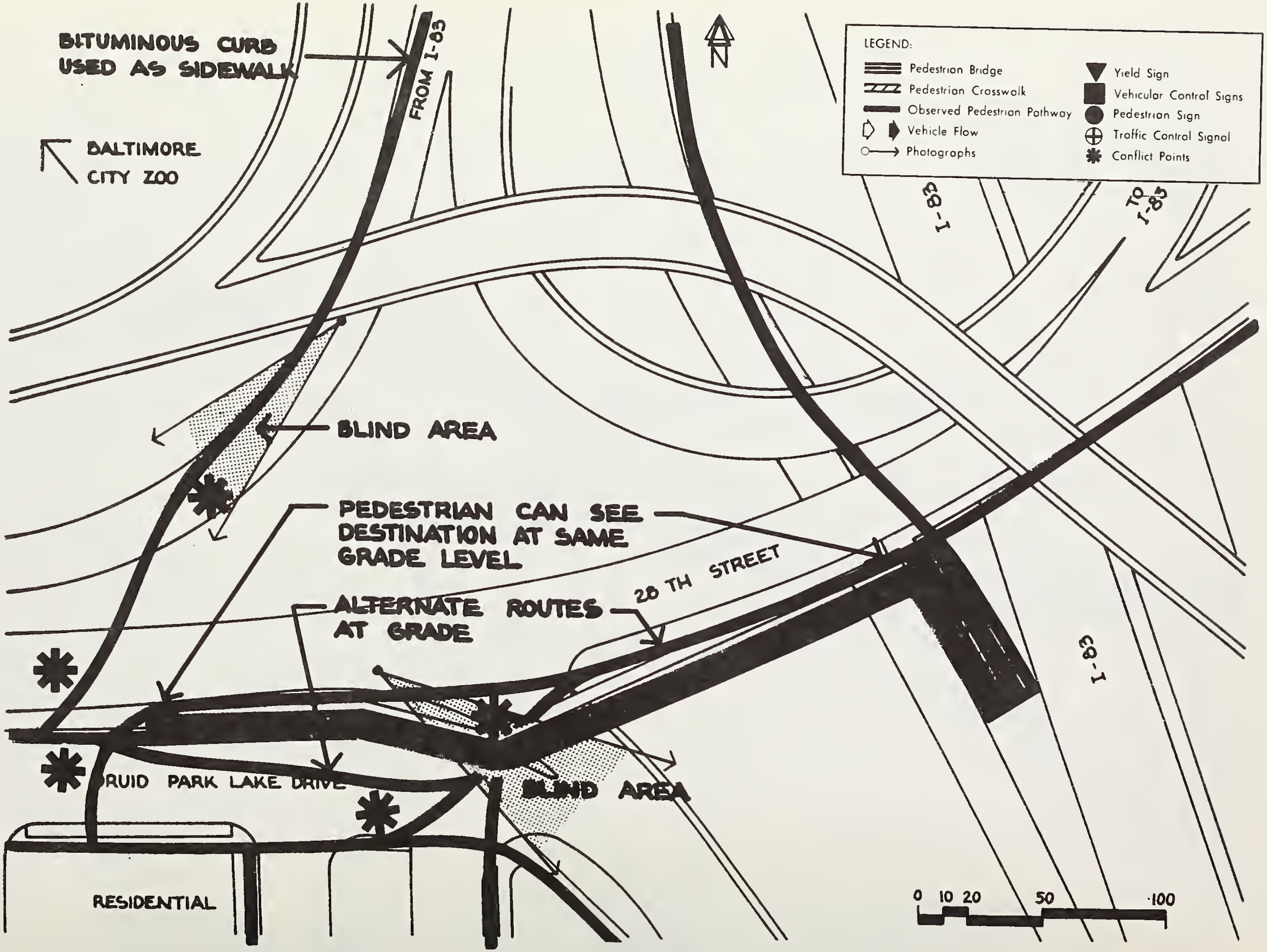


Figure 21. Pedestrian movement near the pedestrian bridge.

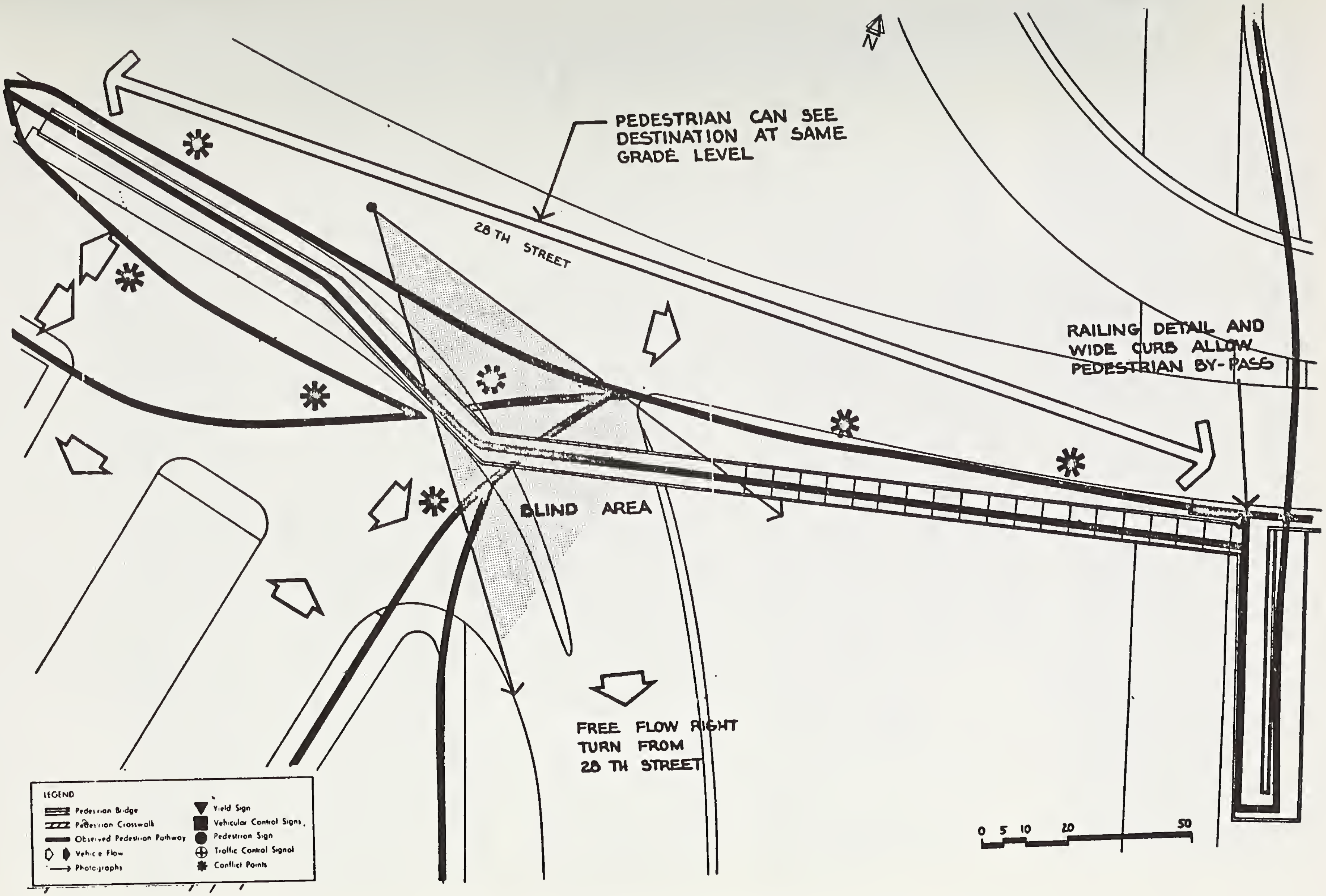


Figure 22. Pedestrian movement at the bridge.

Several additional conflict points result from pedestrian deviation from the prescribed pathway. One set of these conflict points occur around the pedestrian bridge structure itself, where at-grade alternatives to the bridges enable surface crossings of the free-flow turnoff from 28th Street and the adjacent service streets. A second set of conflict points, arising from the use of the bituminous curb along the north side of 29th Street, occur at the roadways which separate this path from the southwest activity area. The final conflict point, located on the 29th Street roadway at the turnoff to southbound I-83, presumably results from pedestrian confusion as to the ultimate destination of the path.

3.2.4.2 Effectiveness of the Interchange Components

Pedestrian/Vehicle Awareness

The configuration of the interchange requires drivers to pay strict attention to directional signage and vehicular maneuvers. These demands tend to remove drivers' visual orientation from potential pedestrian incursions onto the roadway, which may not be anticipated in an environment so obviously dominated by vehicular traffic considerations.

This awareness problem is aggravated by restrictions on driver visibility of pedestrians, particularly at locations where pedestrians deviate from the planned pathways. This situation is particularly critical at three locations. The first such conflict point occurs on 29th Street at the turnoff to southbound I-83. The horizontal and vertical curvature of the roadway obstructs driver visibility of crossing pedestrians. At the point where visibility is regained, the vehicles are only 50 feet away from the pedestrian and can be travelling at speeds in excess of 35 mph. The second location is further down the same 29th Street roadway as it passes under the westbound exit ramps from northbound I-83. The bridge structure obscures the movement of pedestrians who bypass the entire pedestrian bridge structure to use the bituminous curb along 29th Street. The third location is directly under the pedestrian bridge structure, where the base of the bridge restricts driver visibility of pedestrians using the at-grade alternative to the bridge.

With the exception of the lighting fixtures alongside the scissors ramp beneath the 28th Street roadway, no lighting provisions have been made specifically for the needs of pedestrians. Illumination of the overall interchange is provided from standard highway fixtures which are adequate for pedestrians to find their way through the interchange.

The level of illumination provided is not, however, sufficient to make pedestrians easily visible to drivers.

No provisions have been made to assist the pedestrian in navigating the complex pedestrian accommodations of the interchange. The pedestrian must orient himself solely on the basis of his visual perception of the interchange. Directional confusion can result in hazardous deviations from the prescribed pathways. In addition, a visual survey of the interchange can also result in the identification of alternatives to the provided pedestrian accommodations.

Controls on Pedestrian Movement

Although the routes provided for pedestrian travel generally correspond to the actual desire lines, there are two exceptions which result in deviant pedestrian movement. The first is the 29th Street to Druid Hill Park Drive desire line which is accommodated by the pedestrian ramp and bridge structure. The alternative route, which uses the bituminous curbing along 29th Street, results in a smaller distance to travel and eliminates the inconvenience of grade changes associated with the use of the bridge. The second instance of accommodation not directly responding to travel desire lines involves the placement and design of the pedestrian bridge itself. Although the apparent desire line extends west along the sidewalk on the south side of the service road, the western terminal of the bridge is located in the median strip directly across the service road. The effort involved in climbing over the bridge and ramp structure also discourages use of the facility. The inconvenience associated with the use of the provided accommodation results in pedestrian disregard of the planned pathway and, consequently, increased accident hazard.

No barriers, screens, or signs (other than those prohibiting pedestrian encroachment onto the expressway proper) exist to restrict or direct pedestrian movement. Railings, typically provided as a security against pedestrians falling from elevated bridge structures, are used in only one instance to control pedestrian movement. This occurs where the scissors ramp, the ramp-steps of the pedestrian bridge, and the south sidewalk of the 28th Street roadway meet at a single point. At this location, the railing of the pedestrian bridge turns out, across, and back along what would be the extension of the 28th Street sidewalk further towards the west. The intended effect of this configuration is to direct pedestrian traffic from the 28th Street sidewalk onto the pedestrian bridge, preventing further travel at grade along 28th Street. This is negated, however, by the wide curb detail which makes at-grade travel beyond this point possible without walking in the roadway itself. The absence of effective pedestrian countermeasures throughout the interchange facilitates pedestrian deviation from the provided accommodations.

The planned pedestrian crossing of the southbound I-83 exit ramp near Druid Hill Park is potentially hazardous to pedestrians because of the heavy traffic volumes and high speed (up to 50 mph) of the vehicles. Topographic features at this location would have facilitated the construction of a pedestrian bridge, which would have resulted in no additional vertical displacement of the pedestrian pathway.

Controls on Vehicle Movement

The configuration of the interchange was devised to facilitate the free-flow movement of heavy traffic volumes at high speed. In response to this objective, no restrictions on vehicle flow were imposed as a result of pedestrian needs.

3.2.4.3 Illustrative Design Improvements

One approach toward reducing the pedestrian-related problems of this interchange is illustrated in Figures 23 through 27. The major objective was to control pedestrian movement through the interchange to eliminate all conflict caused by intended crossings or unplanned pedestrian incursions into the vehicular roadways. The comprehensive nature of the suggested improvements results in the removal of all pedestrian interference with vehicle flow and, as a consequence, no need to make drivers aware of pedestrian movement.

Controls on Pedestrian Movement

In order to facilitate effective control of pedestrian movement, the number of permissible paths through the interchange has been reduced. Since only one path is available at each entry point, pedestrians do not risk the selection of an inappropriate route and, consequently, will not be forced to deviate from the pathway in order to reach their destination. The elimination of some paths, however, results in longer travel distances and inconvenience caused by required changes in vertical displacement (e.g., pedestrian bridge, ramps) for some routes.

A comprehensive set of countermeasures has been provided to prohibit unplanned pedestrian incursion onto the vehicular roadways. The intended routes have been carefully fenced to confine pedestrian movement to the provided accommodations. The curbing which delineates the ramp roadways should be designed to discourage pedestrian use.

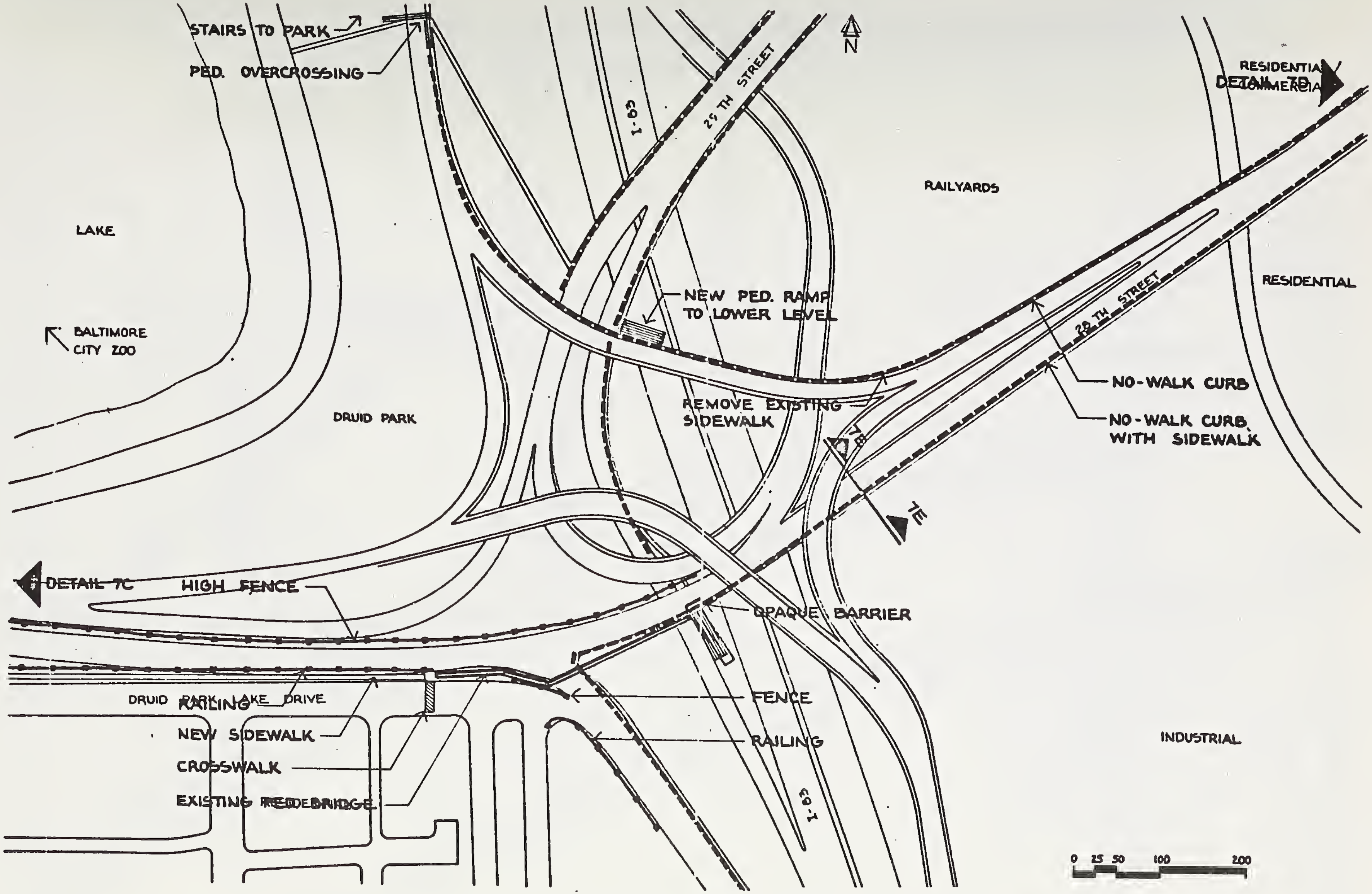


Figure 23. Suggested improvements - 28th St./ I-83.

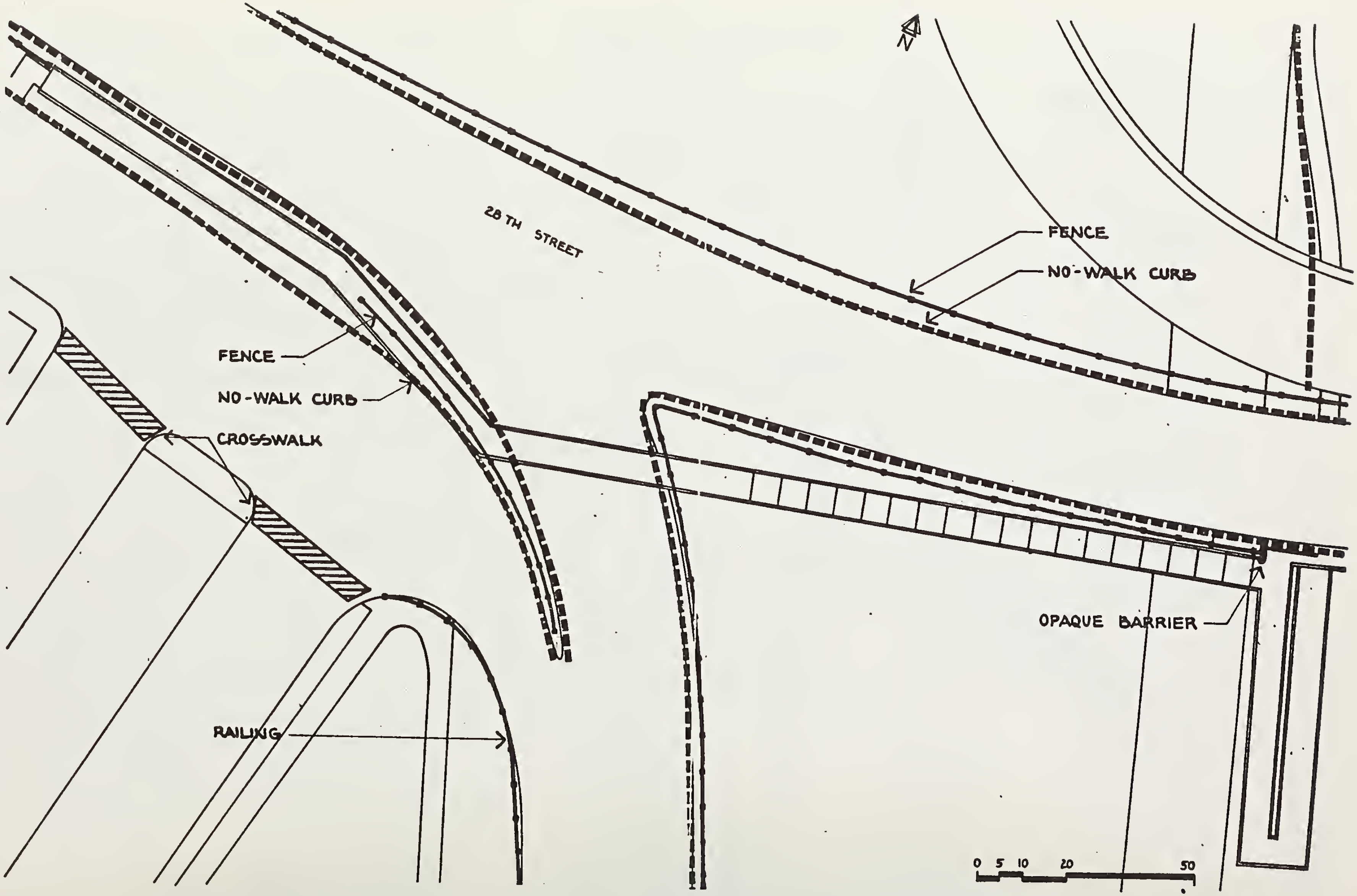


Figure 24. Suggested improvements at the pedestrian bridge.

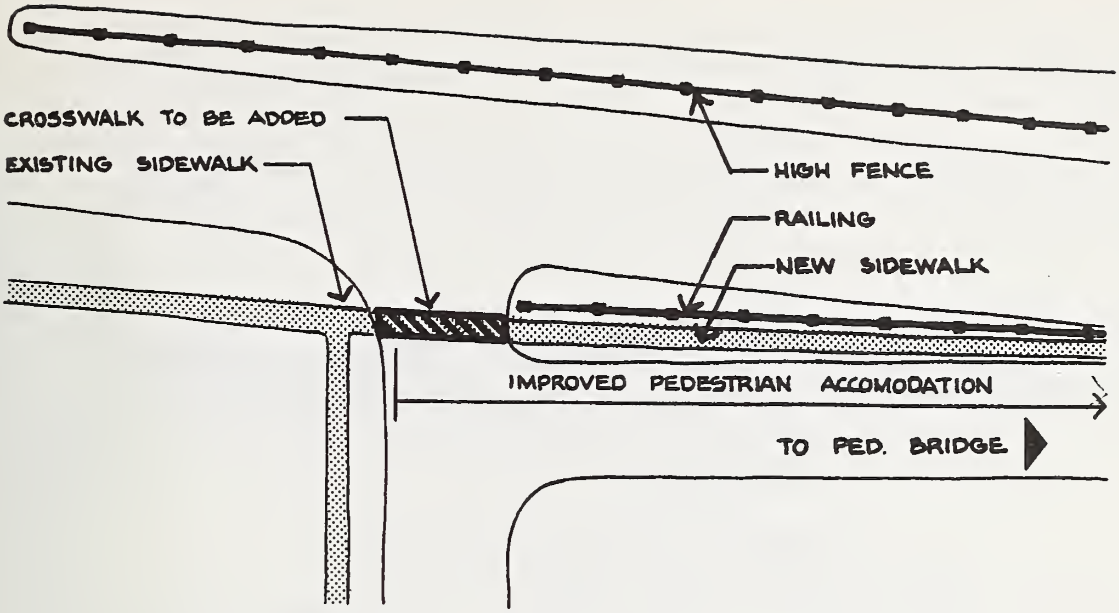


Figure 25. Pedestrian accommodations at western terminal of 28th St.

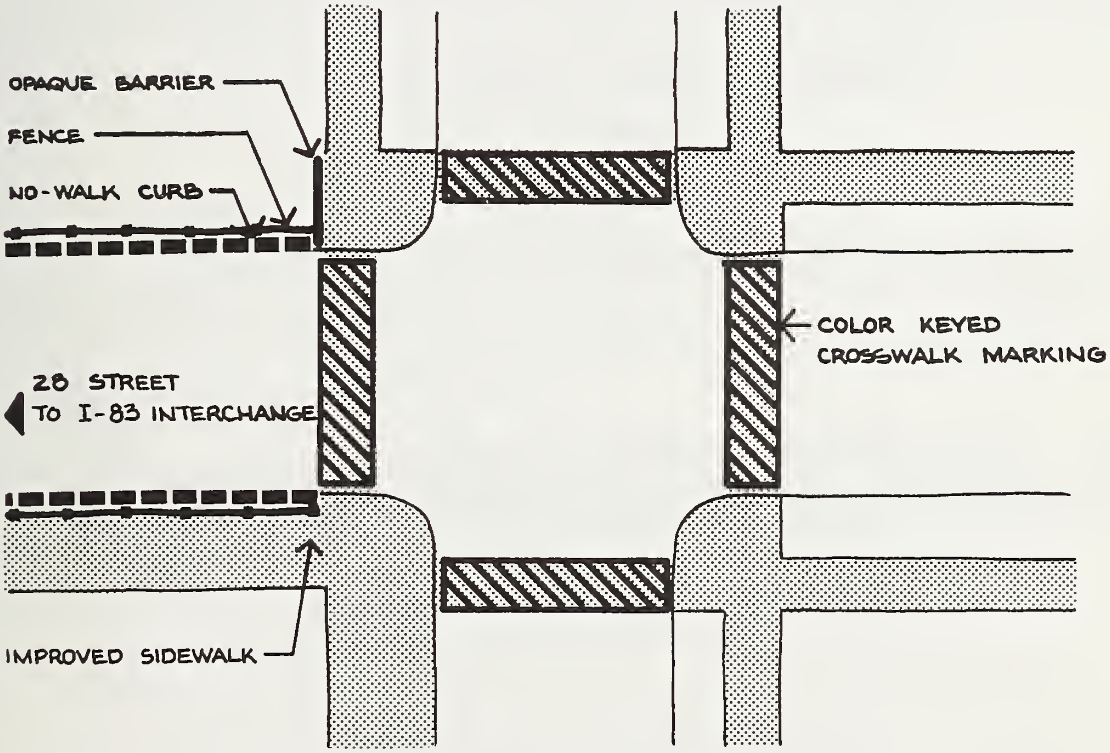
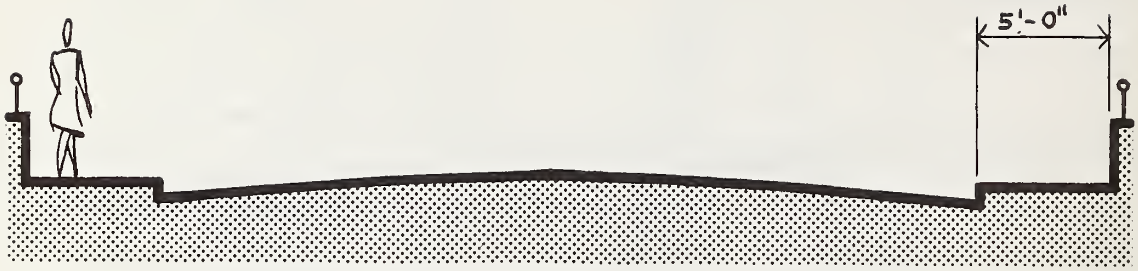
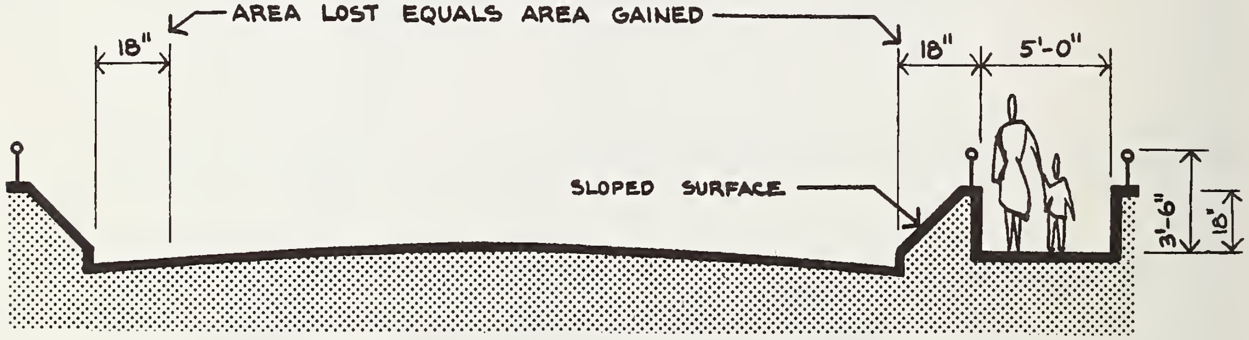


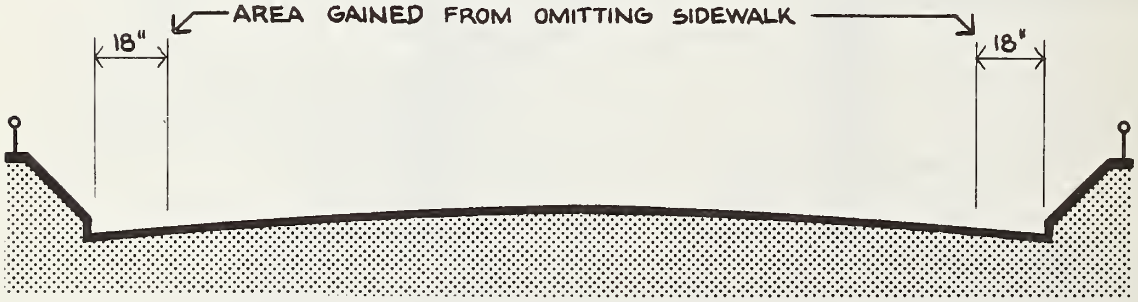
Figure 26. Pedestrian accommodations at eastern terminal of 28th St.



EXISTING



IMPROVED WITH SIDEWALK
ONE SIDE



IMPROVED WITH NO SIDEWALK

Figure 27. 28th St. ramp sections.

Pedestrian/vehicle conflicts on the southbound I-83 off ramp have been eliminated by the use of a pedestrian overpass. The topography of the location results in no additional vertical displacement, since a change in grade is required to permit access to the park. Because the northern 29th Street path has been eliminated, an additional pedestrian ramp is needed to provide for the 29th Street-Druid Park movement.

Controls on Vehicle Movement

Vehicle flow through the interchange is not impeded by pedestrians. The curbs to discourage pedestrian use, however, can pose hazards to vehicles if not carefully integrated into the design.

Pedestrian/Vehicle Awareness

Because pedestrian movement within the interchange is spatially separate from vehicular traffic, typical considerations such as visibility were eliminated. However, the provision of pedestrian-related directional information is needed because the complexity of the interchange and the limited number of pathways available complicate the choice of an appropriate pathway. Directional signs should reduce pedestrian deviation from the planned walkways caused by confusion. Planned pathway utilization is also enhanced by the use of an opaque barrier at the existing scissors ramp; this visual obstruction serves to discourage the perception of alternative (and hazardous) pedestrian routes.

Discussion

The high vehicular design standards of this directional interchange prohibited the use of restrictive traffic control devices. Consequently, in order to eliminate the extremely severe conflict points, pedestrian movement had to be segregated from vehicle traffic by the provision of costly overpass structures.

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APPENDIX 1

PROCEDURES FOR THE ESTIMATION OF DELAY

PROCEDURES FOR THE ESTIMATION OF DELAY

Delay is an important indicator of the performance of a traffic control device. Because traffic signals can be used to facilitate pedestrian movement across roadways, a method for estimating the delays incurred by both vehicles and pedestrians was needed. The following complementary equations, based on queueieng theory, can be used to identify delay trade-offs between alternative traffic control methods for particular applications.

Uncontrolled Crossings - Pedestrians

$$\bar{d} = \frac{\exp(-qI) - qI - 1}{q} = \text{delay/person, in seconds} \qquad (1)$$

where:

q = vehicular approach volume, in veh/hr.

I = pedestrian crossing time, in seconds, $= \frac{W}{3.5} + 3$

W = length of pedestrian path across roadway, in feet

The delay equation was derived from Tanner, reference (16). The equation for pedestrian crossing time was taken from reference (15).

Fixed-Time Signals - Pedestrians

$$\bar{d} = \frac{U[C-(P-I)]^2}{2C} = \text{delay/person, in seconds} \qquad (2)$$

where:

C = cycle length, in seconds

P = duration of the pedestrian crossing interval, in seconds

U = proportion of pedestrians who conform to the signal.

This delay equation was taken from Jacobs, reference (7).

Fixed-Time Signals - Vehicles

$$d = \frac{0.45C(1-g)^2}{1 - gX} + \frac{1620X^2}{q(1-X)} = \text{delay/vehicle, in seconds} \qquad (3)$$

where:

X = degree of saturation, = q/gs

g = proportion of the cycle which is effectively green

S = saturation flow of approach, in veh/hr.

Saturation flow is the maximum flow rate with no signal impedance. This equation, developed by Webster, reference (18), is not sensitive to impedance to turning vehicles caused by heavy pedestrian flows; see reference (14).

Pedestrian-Actuated Signals - Pedestrians

$$\bar{d} = \frac{ta\ 0.5\ \lambda(tb)^2 \exp(\lambda tb - \lambda ta)}{1 + \lambda\ (tb + P) \exp(\lambda tb - \lambda ta)} \quad = \text{delay/pedestrian, in seconds} \qquad (4)$$

where:

ta = minimum lag between actuation and signal response, in seconds

tb = minimum vehicular green time, in seconds

= pedestrian volume, in peds. /second

For conditions of heavy pedestrian flow, the delay characteristics are comparable to a fixed-time signal of cycle length $tb + tg$. The equation was taken from Thedeen, reference (17).

Pedestrian-Actuated Signals - Vehicles

In order to facilitate comparison with the delays produced by fixed-time signals, the following equation can be used to estimate the average proportion of time allocated to vehicular movement:

$$g = \frac{tb + (1/\lambda) \exp(-\lambda tb + \lambda ta)}{P + tb + (1/\lambda) \exp(-\lambda tb + \lambda ta)} \quad = \text{proportion of cycle effectively green} \qquad (5)$$

This value can be directly input into equation (3) above to estimate the average delay per vehicle. The equation for estimating the average proportion of green time was taken from Thedeen, reference (17).

APPENDIX 2

POTENTIAL CASE STUDY LOCATIONS: PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

POTENTIAL CASE STUDY LOCATIONS:

PEDESTRIAN / VEHICULAR CONFLICT

AT EXPRESSWAY INTERCHANGES

Summary of Prototypical Situations as seen in the Identification Survey

The identification survey documented herein has attempted to examine a wide range of current problems associated with pedestrian movement which occurs within highway interchanges and, more specifically, the current or potential impacts of pedestrian movement occuring at the terminal of the interchange vehicular free-flow ramps. The surveys documented herein include an examination of all pertinent factors which contribute to pedestrian/vehicular conflict in highway interchanges. The intent of examing the fifteen following interchanges was to determine which of these potential and prototypical sites maximizes the opportunity for further analysis and evaluation of the issues currently under consideration by FHWA.

In all cases examined there were mitigating circumstances that required pedestrians to move through the highway interchanges. This was principally due to the following characteristics of the interchange environment:

a. The linkage of peripheral land uses — in most cases the expressway bisected two or more major land uses that normally require pedestrian linkage and accessibility on foot, such as

   - Schools to residences trips
   - Residences to shopping trips
   - Residences to recreation trips
   - Parking to places of employment trips

   Since in all cases the expressway was either depressed or elevated with reference to abutting properties, the secondary arterial which comprises the other axis of the intersection including its free-flow ramps constitutes the only access by foot linking these activities. In some cases, due to the distance between expressway intersections and due to the absense of any secondary non-intersection expressway crossings, there is a high degree of pedestrian movement which occurred within the interchange environment. Often pedestrian movement was discouraged due to the distance across the intersection or a major fence barrier completely circumventing and enclosing the intersection environment, precluding the propensity for any pedestrian movement.

b. In other instances it was obvious that the expressway and the resulting intersection had been added to an already existing and operational neighborhood or community with little regard paid to the relationships of land use activities within the community. Because these activities require pedestrian linkage, conflict occurs throughout the intersection environment and the issues of interfacing the intersection with neighborhood pedestrian movement patterns remains unresolved.

The preliminary surveys that follow offer evidence that four prototypical situations exist in terms of the interface of pedestrian movement, highway interchanges and vehicular free-flow ramp terminals:

1. Multi-directional vehicular interchange including a complete pedestrian movement network.

   This can be characterized by a multi-directional interchange composed of a complex configuration of roadways and free-flow ramps, with some specialized accommodation for pedestrian crossings. This pedestrian network for the most part is complete and does provide the ability, if utilized, for pedestrians to move through the vehicular interchange free from vehicle conflict. However, most often this network system is not utilized one hundred percent and due to a lack of properly designed and located countermeasures, the pedestrian often has alternative routes which may be more convenient and accessible to him, thereby resulting in situations of conflict and high risk in terms of pedestrian safety.

   Interchanges of this type documented in the identification survey include: I-95 and Seminary Road; and the Cincinnati example.

2. Multi-directional interchange including an incomplete pedestrian movement network.

   This is characterized by specific but incomplete accommodations being provided for the pedestrian and, due to the failure to provide effective countermeasures and controls, the movement accommodations improperly direct the pedestrian. This results in a more dangerous, but preferred, route of travel. In addition, the pedestrian movement network itself is incomplete, allowing the pedestrian to move partially through the interchange free from conflict. However, for the remainder of time that the pedestrian spends moving within the intersection environment there are no accommodations. This results most often in numerous conflict points occuring where actual pedestrian pathways and vehicle ramps directly interface. In these situations it is both the lack of countermeasures and the discontinuity of the pedestrian movement network that contributes to conflict.

   Interchanges which follow this classification include: I-83 and 28th Street; and portions of the Cincinnati example.

3. Standard interchange configurations / Minimum pedestrian accommodation.

   This can be characterized as simple grade-separated interchanges such as the "clover-leaf" and "diamonds" geometric designs, with sidewalks or unpaved paths being utilized by pedestrians. In this case, due to the lack of accommodations for pedestrian movement, controls and countermeasures, the pathway utilized by the pedestrian is left to his own discretion. He proceeds through the interchange with his pathway and movement decisions solely determined by his own perception of his risk and safety.

   Examples of this type are: I-495 and New Hampshire Avenue; Baltimore-Washington Parkway and Annapolis Road; and I-695 and Liberty Road.

4. The terminal of the vehicular free-flow ramp with no pedestrian accommodations/The micro environment problem.

This includes problems of physical control and design at the micro-scale. In particular, it focuses on problems dealing with the precise manner of junction of expressway free-flow ramps to surface streets and the related effects on pedestrian crossing and vehicular flow. Most often the terminal of the expressway ramp is the place where the driver must negotiate a merge with traffic moving on a secondary arterial. This situation self-regulates vehicular operating characteristics in terms of speed, orientation, driver awareness and continuity of movement. In most cases examined, however, the foremost constraint to the capacity of the terminal and the driver's ability to complete the transition between arterials and expressways is inhibited by pedestrians moving across the free-flow ramp terminal. In some instances controls are employed to increase driver awareness, restrict vehicle flow, or retard pedestrian movement (i.e., signs, fences and signals).

Example interchanges include: the E Street Expressway at D Street/Virginia Avenue; I-83 at Charles Street; and I-83 at St. Paul/Mt. Royal.

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Urban Baltimore

Interchange Identification: I-83 / 28th Street
(Street name and route number)

Pedestrian Count: 4 people in 1 minutes

Vehicular Count: Constant free-flow

Time of Observation : from 9:30 until 12:00 noon

NOTES :

1. Land Use: To the west of this interchange is a large urban park, the Baltimore City Zoo, and a large residential area. To the east is a large residential community and neighborhood convenience shopping. This creates a substantial amount of pedestrian (including children) movement within the intersection due to the necessary linkage of adjacent land uses.

2. Overall distances across I-83 are substantial.

3. Person walking west along 29th Street and east and west along 28th Street accommodated by sidewalk alongside ramp and roadway structures.

4. Pedestrian walking west on 29th Street faces decision point midway across the I-83 ramps. If on north sidewalk of ramp, he may continue, or, seeing pedestrian bridge structure in distance to the southwest, may elect to cross ramp to other sidewalk. This point of conflict further aggrevated by roadway configuration, creating blind area for left half (or southern half) of rampway. Pedestrian in this part of road is hidden from view of 30-40 MPH ramp traffic.

5. Curve and slope of this ramp (29th Street to I-83 southbound) continues to hide pedestrians using sidewalk on driver's left. Creates hazardous, but not conflicting, situation.

6. Continuation of 29th Street north (driver's right) sidewalk eventually terminates in middle of median strip between roadways of same direction, not adjacent to any use or developed parcel. This tends to make use of this sidewalk minimal, maximizing use of bridge structure and increasing conflict potential described in (4) above.

(Following notes refer to Pedestrian Bridge Detail)

7. Bridge structure for pedestrians consists of following: (starting from west progressing towards east)

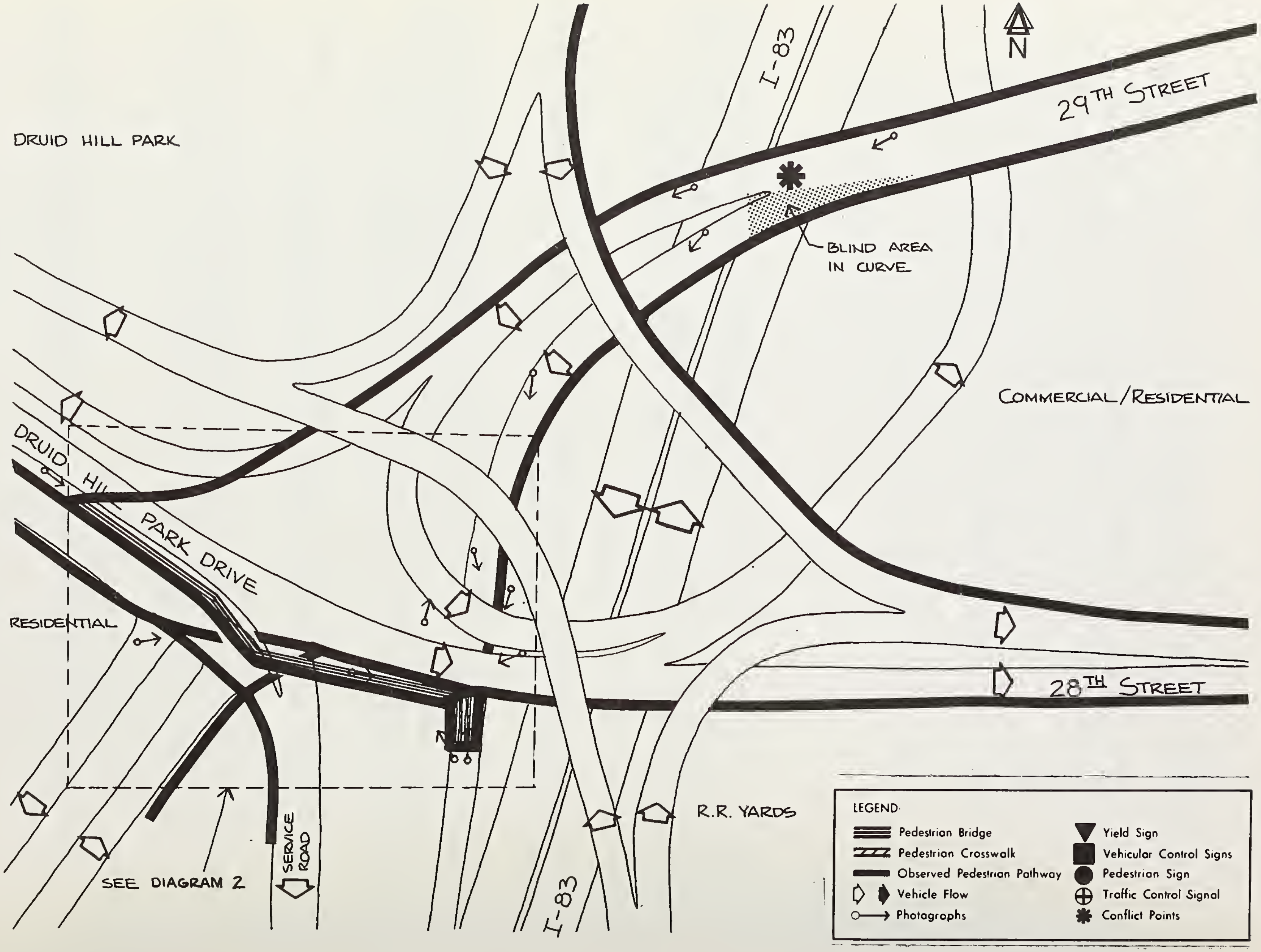

Figure 28. 28th St./I-83.

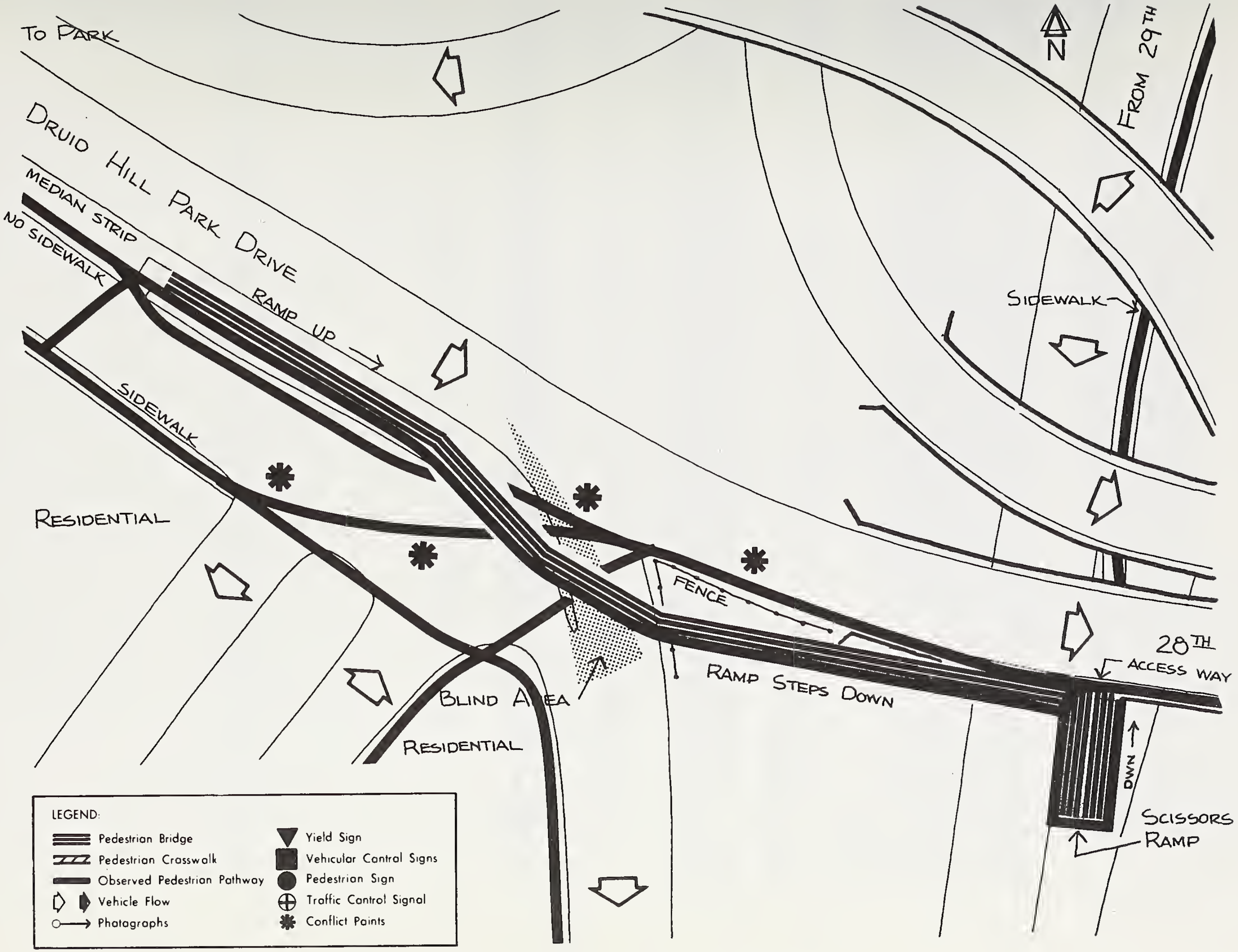

Figure 29. 28th St./I-83 detail.

- Sidewalk from street to foot of ramp
- Ramp up at moderate slope
- Bridge over free-flow turnout
- Sloping wide steps (ramp steps) down to approximate original level
- Opening to sidewalk along 28th Street on left, ramp down and under to right
- Scissors ramp structure carries pedestrian underneath 28th Street-ramp/roadway, finally heading in northerly direction
- Sidewalk links scissors ramp to sidewalk along 29th Street—I-83 south ramp — following curve to north, then east.

8. Pedestrian bridge accommodation is not entirely effective due to lack of countermeasures. Alternate travel routes are readily apparent at each end of bridge structure. Ramp steps easily by-passed along 2′ wide curb detail along north side of ramp structure. Route may be continued at grade to either foot of opposite ramp, or residential street sidewalk opposite from ramp. Solid ramp structure creates blind spot for drivers using turnout — hiding pedestrians using either of these alternate routes. Worn paths in ground indicate heavy utilization of these alternates.

9. Ramp steps easy for descent, more difficult to climb. Discourages use, aggrevates condition noted in (8) above.

10. Path in ground westward from ramp down center of median strip indicates heavy non-sidewalk pedestrian travel, following long distance pedestrian travel desire lines. See diagram below:

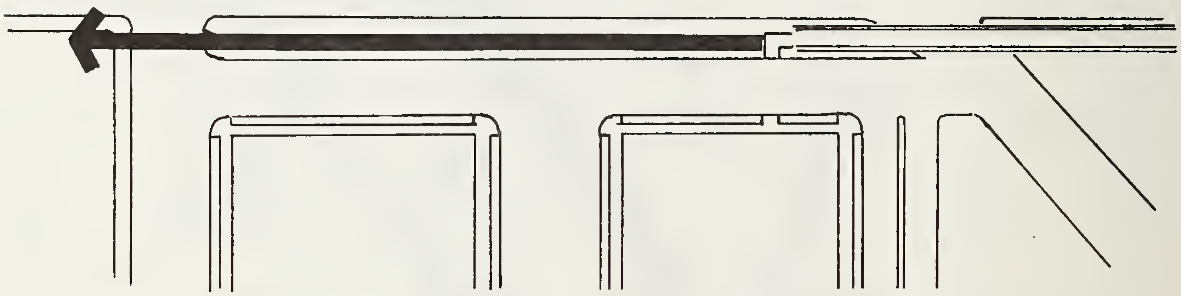

Figure 30. Heavy non sidewalk pedestrian travel

11. Pedestrian traffic is directed alongside vehicular movement throughout interchange and must interface with this movement at several locations.

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Urban Baltimore

Interchange Identification: I-83 / Charles Street
(Street name and route number)

Pedestrian Count: 7 people in 5 minutes

Vehicular Count: Constant Free-Flow

Time of Observation : from 10:15 until 10:30 AM

NOTES :

1. Tapering of sidewalk creates hazard, altering pedestrian travel line as shown.
2. High volumes of both pedestrians and vehicles make conflict severe.
3. Similarity of this configuration to many other instances makes study significant.
4. Pedestrian is forced to move north along Charles Street to a point partway down ramp. Down slope and high fence obscures him from driver's view.

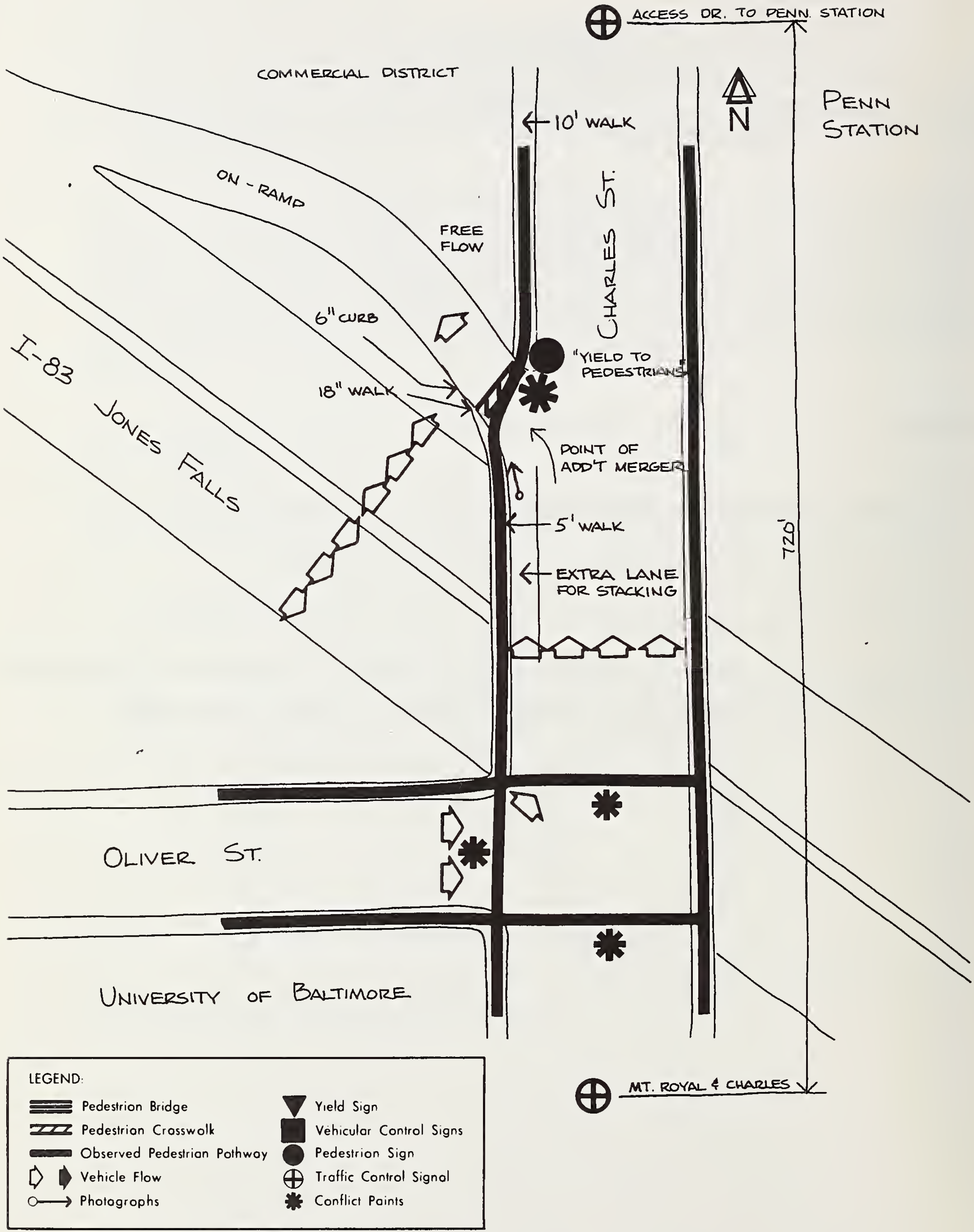

Figure 31. Charles St./I-83

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Urban Baltimore

Interchange Identification: I-83 / St. Paul Street / Mt. Royal Avenue
(Street name and route number)

Pedestrian Count: 4 people in 15 minutes

Vehicular Count: 5-7 vehicles in 15 minutes

Time of Observation : from 10:30 until 10:45 AM

NOTES :

1. Fence to restrict easy short cuts for pedestrians.
2. Over-restricting of natural pedestrian travel desire lines forces consideration of mid-roadway path, far more dangerous than short cuts which were restricted — "safety measures" create a more hazardous condition.
3. Bushes cause blind area in free-flow zone.
4. Sidewalk directs pedestrians into free-flow zone on a ramp beset by visual barriers, creating conflicts and safety hazards.
5. High volumes of pedestrians and vehicles noted simultaneously.

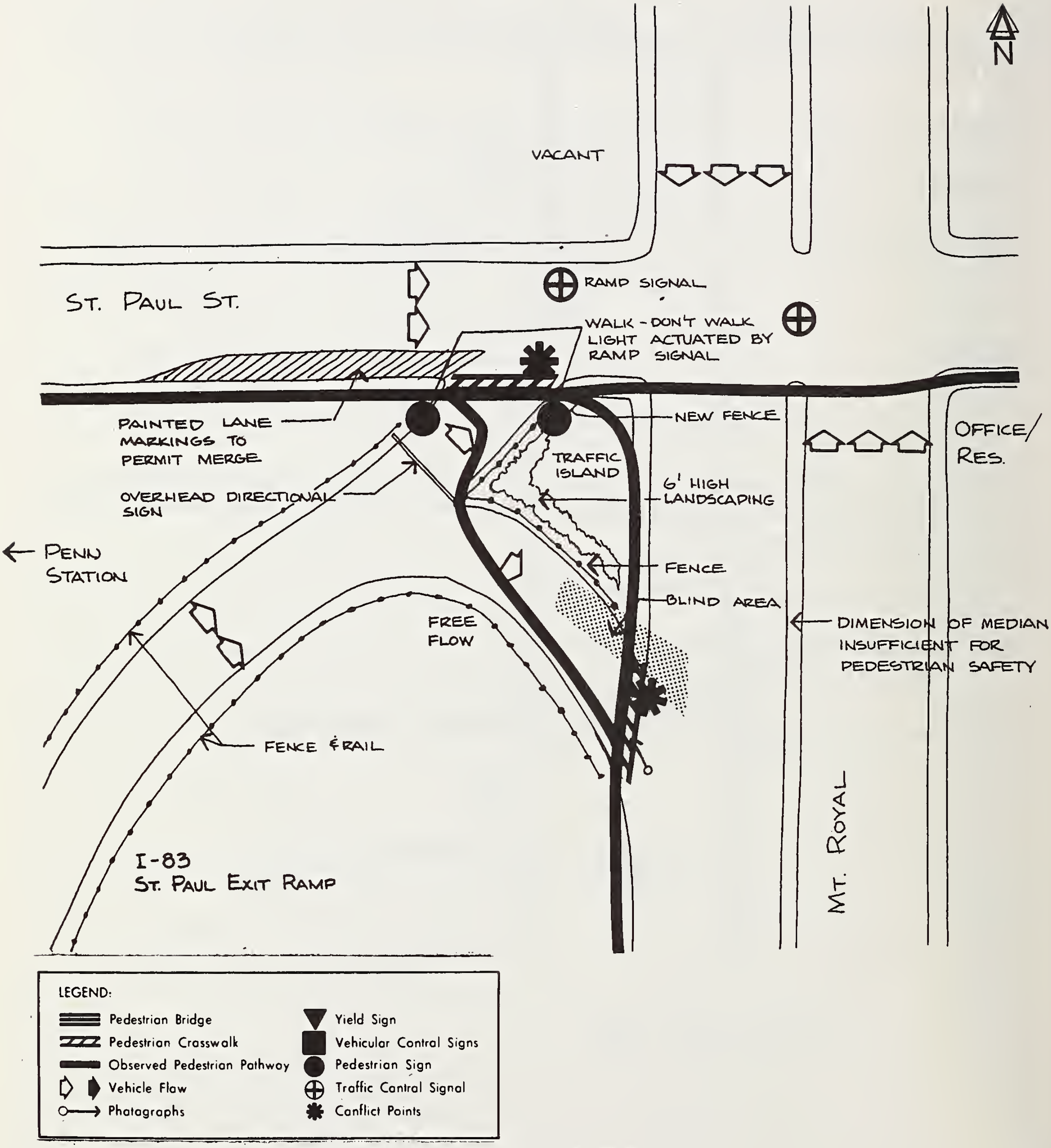

Figure 32. St. Paul St./I-83

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Suburban Baltimore

Interchange Identification: I-695 / Liberty Road
(Street name and route number)

Pedestrian Count: 2 people in 30 minutes

Vehicular Count: Constant Free-Flow

Time of Observation : from 2:15 until 2:45 PM

NOTES :

1. Typical interchange condition and configuration.

2. Many conflict points as sidewalk crosses ramp ends.

3. Transition from service road sidewalk to main road sidewalk in southwest quadrant works particularly well.

4. Unusual sign increases driver awareness.

5. Pedestrian sidewalk configuration is not complementary to desired pedestrian movement patterns. The pedestrian must turn to move along ramp right-of-way then at a distance extending well into the ramp the pedestrian must cross perpendicular to roadway then move along ramp to sideway area. This is typical of most intersection designs and has obviously been done to reduce the duration of time that the pedestrian spends in the ramp roadway itself. Pedestrian often ignores this planned route and continues along a straight line path, increasing his exposure to vehicular conflict.

6. Configuration of ramp connection to street insures that either the driver's or pedestrian's natural visual orientation will be away from the source of conflict, creating an effective "blind" area. This is further aggrevated for driver due to particular angle of ramp relative to cross arterial when merging onto Liberty Road. Angle of the ramp is too close to Liberty Road for driver to easily look directly out of his window at oncoming pedestrians and vehicles. At the same time, the angle of intersection is too great for driver to use rear-view mirrors. Oncoming pedestrians and vehicles are hidden between the two sight-lines.

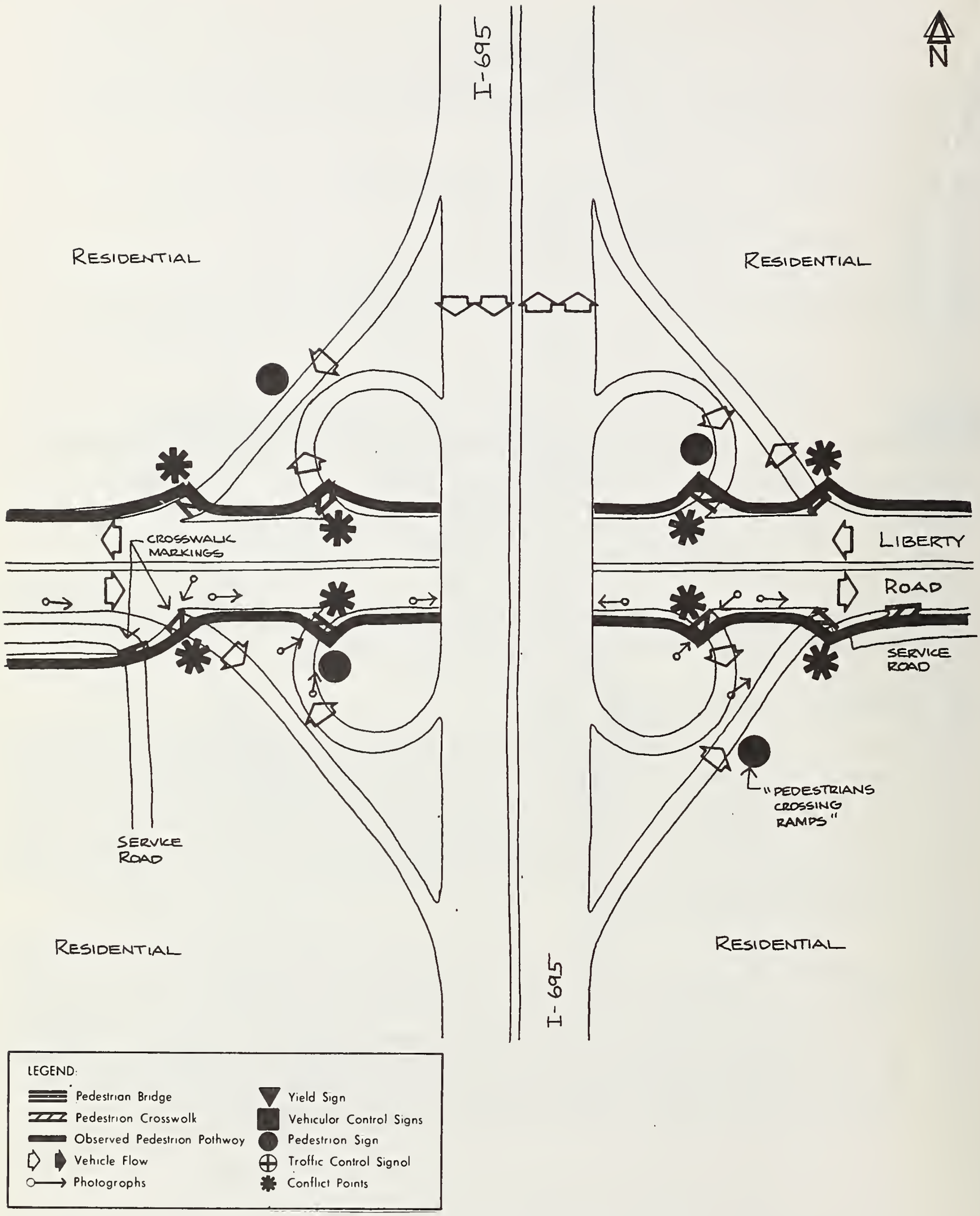

Figure 33. Liberty Road/I-695.

CASE STUDY SURVEY

Interchange Location : Urban Washington

Interchange Identification: E Street Expressway / D Street off-ramp
(Street name and route number)

Pedestrian Count: 60 people in 10 minutes

Vehicular Count: 170 vehicles in 10 minutes

Time of Observation : from 8:40 until 8:50 AM

NOTES :

1. No crosswalk from D Street Plaza to opposite sidewalk when north sidewalk is terminated, forcing random pedestrian movement amongst trucks making deliveries, cars entering garage, and traffic exiting expressway.
2. Slope of off-ramp hides pedestrians in crosswalk until close upon them.
3. Typical free-flow and sidewalk-crosswalk situation at E Street ramp end.
4. Access to garage aggrevates conflict situation.
5. Railing and sign effective in directing pedestrain traffic across D Street further east, a few feet away from garage entrance. This alleviates a high conflict condition to some degree.

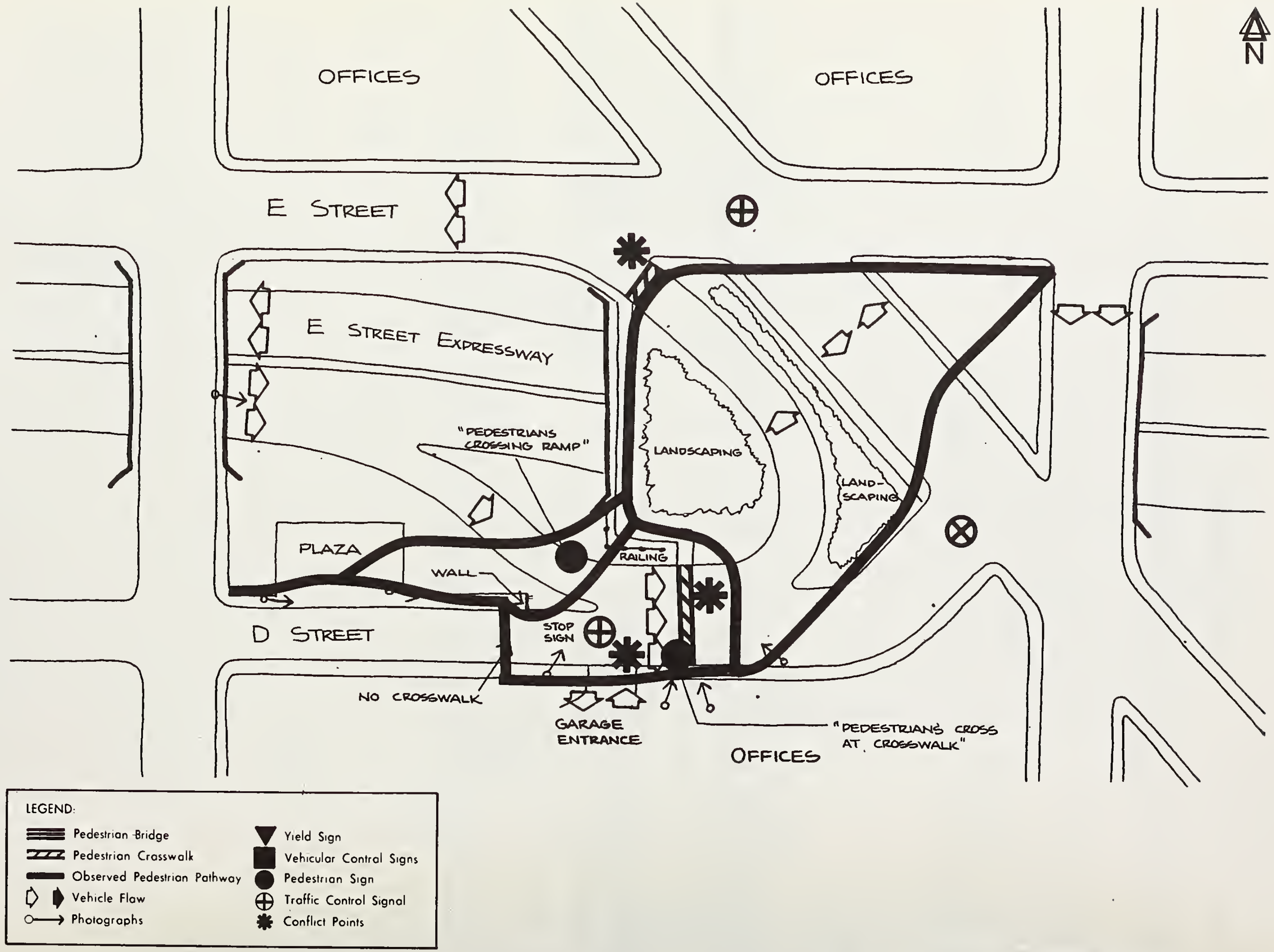

Figure 34. D St. off ramp/E St. Expressway

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Suburban D.C. (Maryland)

Interchange Identification: I-495 & New Hampshire Avenue
(Street name and route number)

Pedestrian Count: 8 people in 20 minutes

Vehicular Count: Avg. 3/1 minute

Time of Observation : from 9:45 until 10:00 AM

NOTES :

1. Discontinuities in sidewalk paths.
2. Traffic light 700-1000 feet north of interchange backs up traffic onto free-flow exit ramp off 495 to north New Hampshire Avenue, blocking pedestrian flow.
3. Much heavier pedestrian traffic between 1 and 7 PM.
4. Pedestrian traffic is predominantly:
   a. Teens
   b. Young mothers
   c. Elderly

   Making trips from housing south of I-495 to commercial north of I-495.
5. Commercial includes neighborhood's only food supermarkets.
6. Same sidewalk/crosswalk at ramp end condition noted at I-695 and Liberty Road.

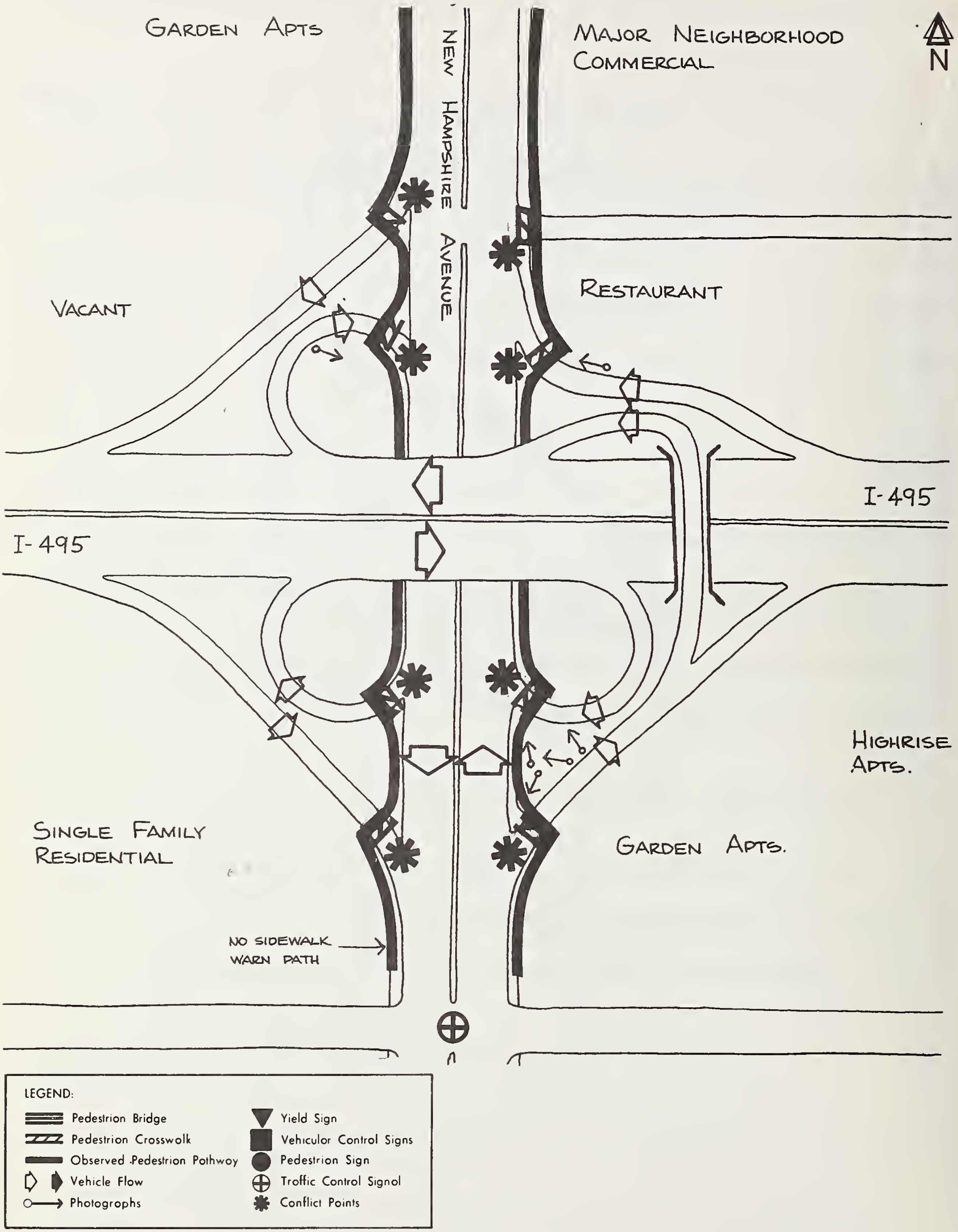

Figure 35. New Hampshire Ave./I-495.

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Suburban D.C. (Maryland)

Interchange Identification: MD. 450 & Balt/Wash. Parkway
(Street name and route number)

Pedestrian Count: 5 people in total during observation.

Vehicular Count: Avg. 4/minute

Time of Observation : from 10:40 until 11:05 AM

NOTES :

1. No sidewalks (except for bridge detail) throughout interchange.
2. Well worn path and litter across parkway each side of Route 450 roadway — indicates pedestrian utilization.
3. Heavier pedestrian travel possible afternoons and weekends between apartments and shopping center.
4. Route 450 overpass slopes and curves, hides pedestrians on other side of "hill" — safety hazard.

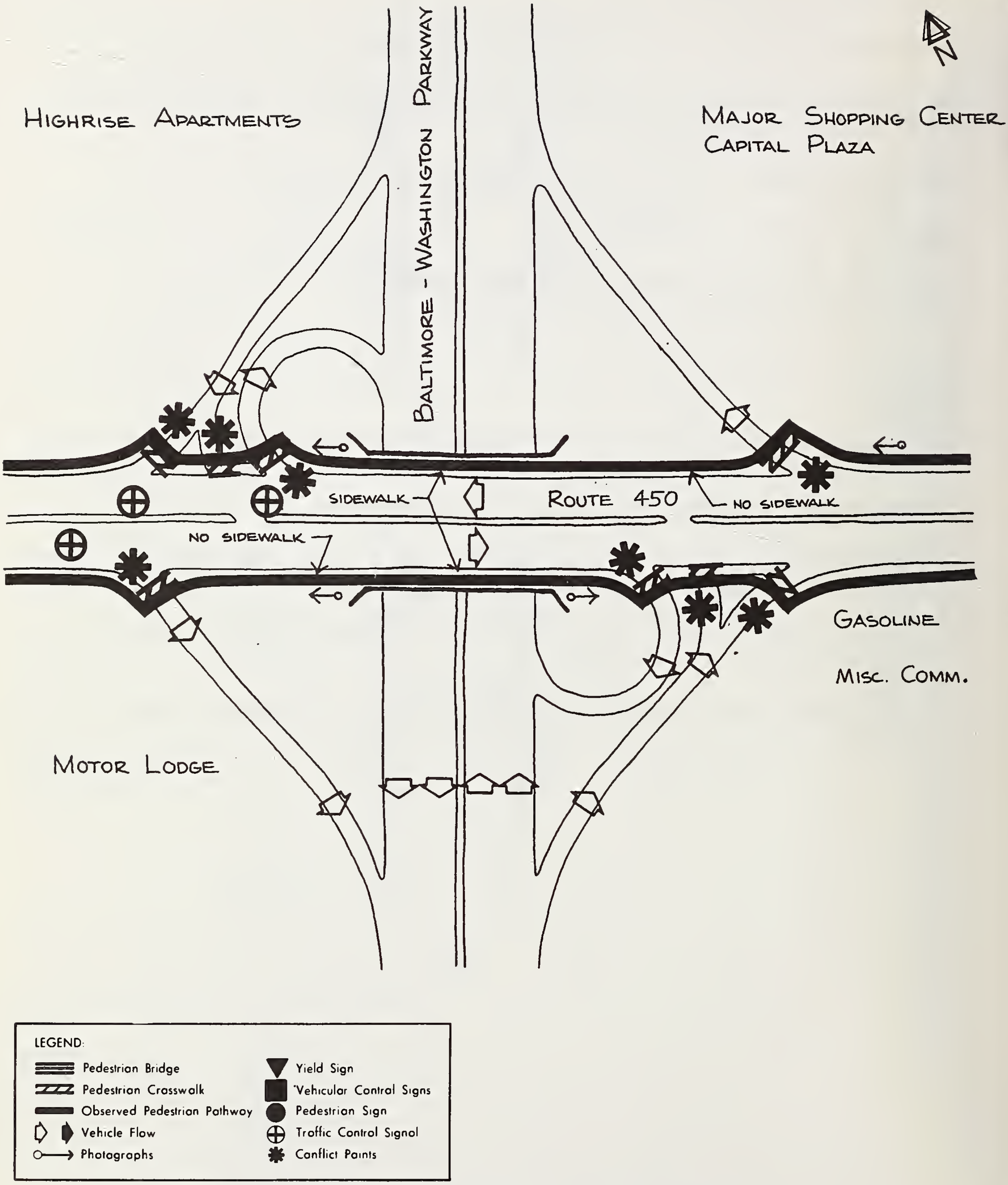

Figure 36. Baltimore-Washington Pkwy./Md. 450

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Suburban D.C. (Maryland)

Interchange Identification: MD. 202 & Balt/Wash. Parkway
(Street name and route number)

Pedestrian Count: 2 people in total during observation

Vehicular Count: Avg. 7/min.

Time of Observation : from 11:10 until 11:40

NOTES :

1. Few pedestrian generators or receivers.
2. Low pedestrian traffic.
3. Pedestrians able to utilize existing stoplight cycles.
4. Sidewalk induces pedestrians to cross at a point 20 to 50 feet up the ramp roadway.

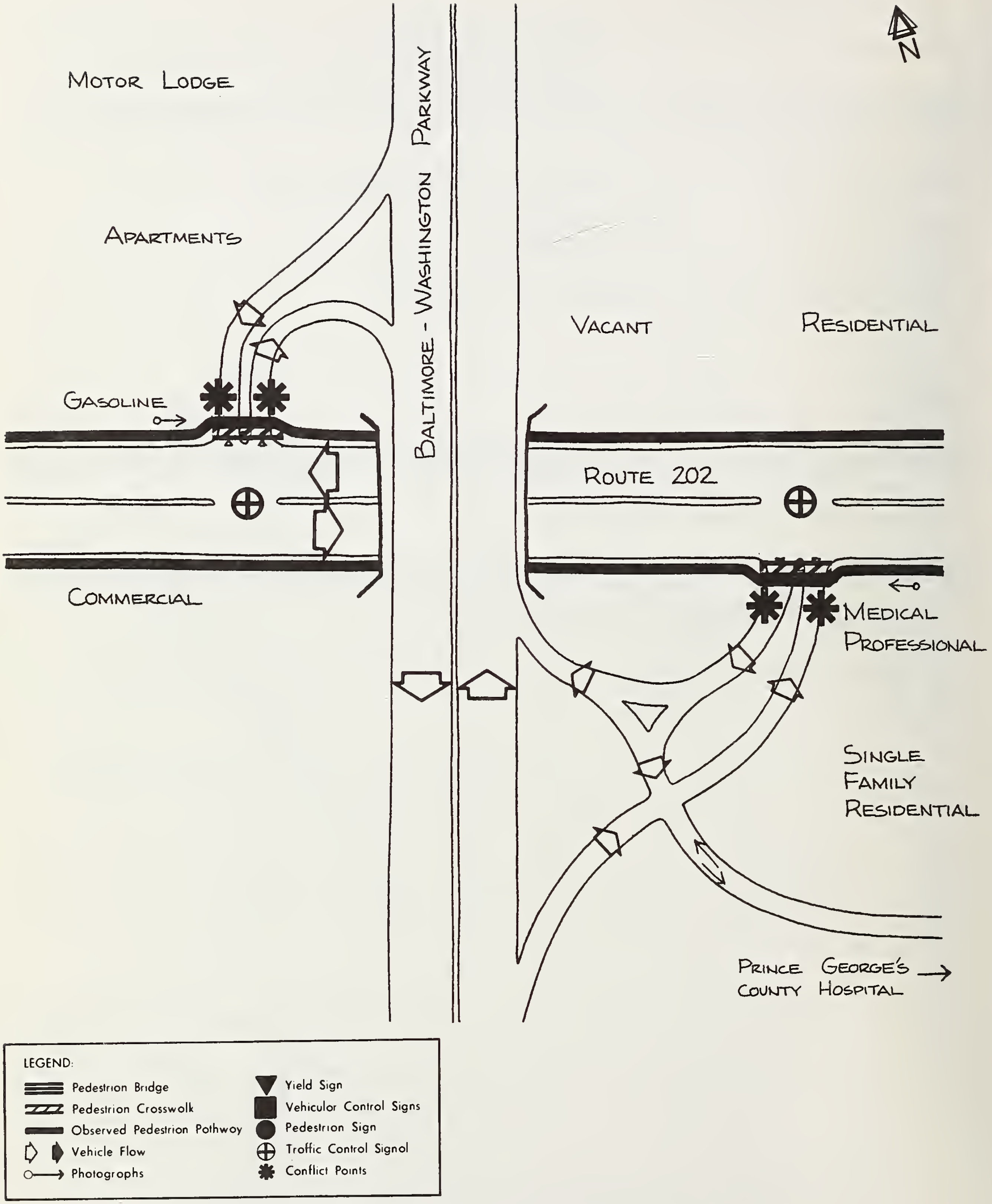

Figure 37. Baltimore-Washington Pkwy./Md. 202

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Suburban D.C. (Virginia)

Interchange Identification: I-95 & Seminary Road
(Street name and route number)

Pedestrian Count: 7 people in 1 minutes

Vehicular Count: Major vehicular flow

Time of Observation : from 2:50 until 3:30

NOTES :

1. Pedestrian bridge is used, distance large but not insurmountable, fairly accessible, steep ramps.
2. Pedestrian bridge main span is sidewalk detail of top level vehicular bridge. Sidewalk portion is narrow.
3. Vehicular direct access from southbound I-95 exit ramp into adjacent apartment parking lot allows easy at-grade pedestrian travel across mid-level service roads. Pedestrian can exit parking lot at ramp access point and cross I-95 at mid-level without climbing steep ramps of bridge structure. Signs prohibit such pedestrian travel, but are ignored.
4. Alongside eastern pedestrian bridge ramp, worn path indicates travel at mid-level as described in (3) above. Again, signs prohibit pedestrian at grade travel, but are ignored. There are no sidewalks in this area.
5. "Unplanned" break in fence at western end of pedestrian bridge ramp allows only access to parking lot and apartments for considerable distance west along Seminary Road. Access to Seminary Road sidewalk and bridge ramp restricted and inconvenient, making illegal mid-level pedestrian travel more desirable.
6. Detailing of ramp structures and curbing and channelizing islands appears and functions as sidewalks and pedestrian safety islands, although dimensionally inadequate for such use.
7. Road and ramp configuration hides pedestrians at several places at secondary mid-level. Illegal mid-level pedestrian travel more convenient but dangerous.

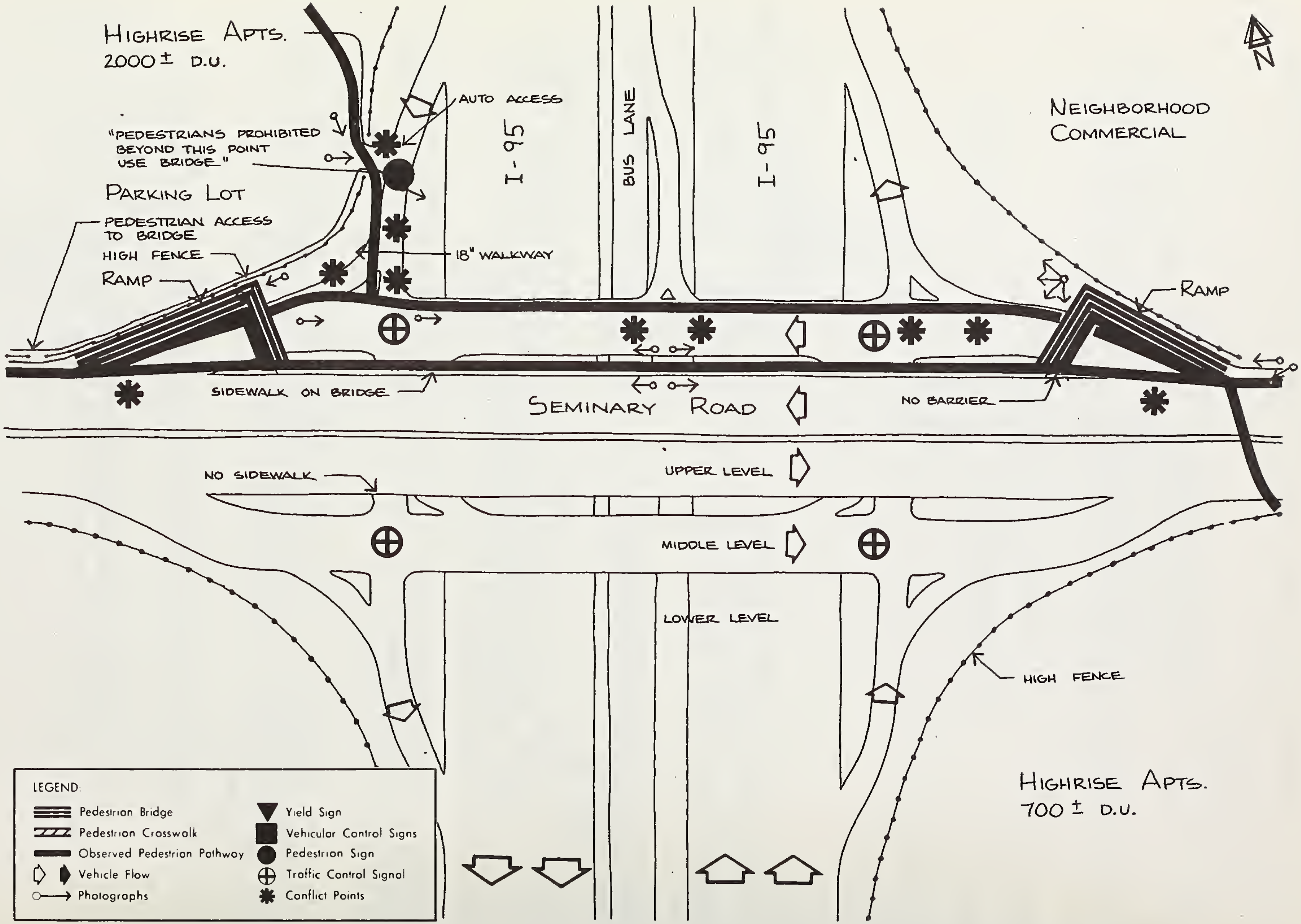

Figure 38. Seminary Road/I-95.

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Urban Wilmington

Interchange Identification: I-95 & Pennsylvania Avenue
(Street name and route number)

Pedestrian Count: 25 people in 20 minutes

Vehicular Count: Constant flow

Time of Observation : from 11:00 until 11:30

NOTES :

1. Free-flow right turn off eastbound Pennsylvania Avenue conflicts with crosswalk. Yield to pedestrian sign not effective.

2. Speed and amount of vehicular traffic negates any existing provisions for pedestrians (i.e., signs, etc.).

3. Proper use of angular sidewalk from Pennsylvania Avenue to park and school in southwest quadrant forces pedestrians to cross path for free-flow traffic heading onto southbound I-95 traffic. Observed as running in front of traffic.

4. Several instances of typical sidewalk/crosswalk vs. ramp traffic conflict.

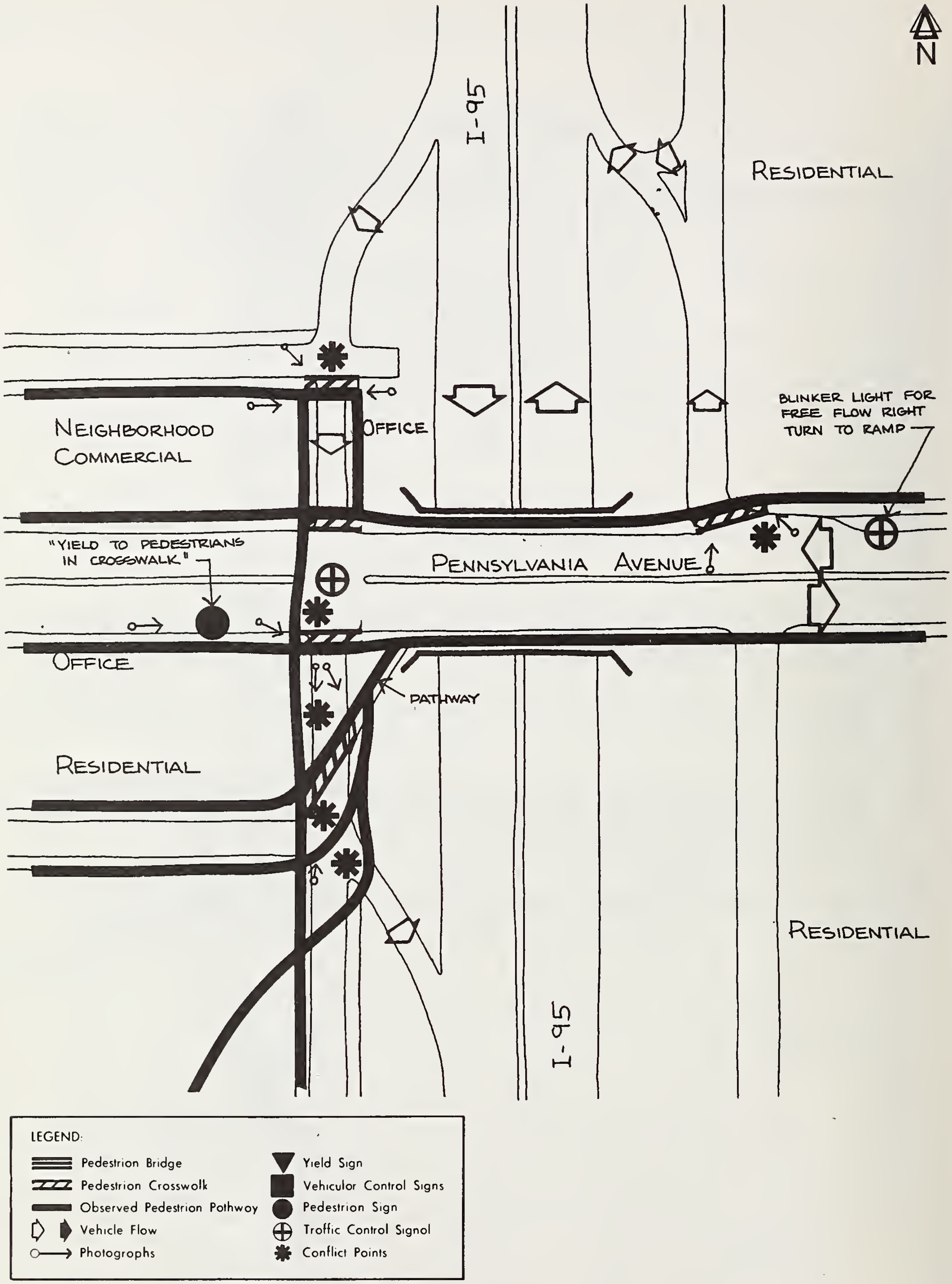

Figure 39. Pennsylvania Ave./I-95.

PEDESTRIAN/VEHICULAR CONFLICT AT EXPRESSWAY INTERCHANGES

CASE STUDY SURVEY

Interchange Location : Urban Cincinnati (Riverfront Area)

Interchange Identification: I-75 and Main/Walnut/Race & Vine Sts.
(Street name and route number)

Pedestrian Count: 30 people in 1 minutes PM
14 people in 1 minute AM
Vehicular Count: 25/min, AM
10/min. PM due to pedestrian delay
Time of Observation : from 5 until 6 PM
7:30 9:00 AM

NOTES :

A. Definition of the Problem:

The expressway configuration between Cincinnati's downtown and the Riverfront Stadium represents several opportunities to examine severe pedestrian/vehicular conflicts in a free-flow interchange situation. The 12-lane interstate expressway system separates Cincinnati's CBD from the waterfront parking areas. These parking areas contain more than 4,000 parking spaces, both in the area of the Stadium and in surface lots along the Ohio River.

The complex expressway configuration is composed of a series of interweaving, free-flow exit and entrance ramps which provide vehicular access and linkage

1. to three major downtown cross streets
2. between two major interstate expressways
3. to waterfront and Stadium parking areas.

At all three locations the system of interweaving expressway free-flow ramps represents a formidable barrier to pedestrian traffic. The environment in the vicinity of the expressway ramp system is entirely vehicle dominated with no evidence of any accommodation for pedestrian movement.

It is obvious that from the standpoint of transportation planning, pedestrian movement was not a consideration in the planning and design of the interstate ramp system. Perhaps it was not contemplated that a heavy volume of pedestrian traffic would be moving from the waterfront parking areas across the expressway ramp system into the downtown to their respective places of work. The pedestrian is asked to negotiate a minimum of five free-flow ramps with no pedestrian accommodations in an environment that is entirely vehicle dominant with no vehicle controls whatsoever.

The high volume of pedestrian commuters moving across this system are most evident between the hours of 4:30 and 5:30 at the end of the work day when commuters exit from the downtown to reach their automobiles. This is not as evident in the morning peak hours, as commuter arrival times are varied. The peak hours for commuter foot traffic are identical to peak-hour driving times and, in fact, this heavy pedestrian traffic is responsible for greatly impairing vehicle accessibility to and from the expressway system.

The heavy pedestrian volumes, 1,000 ped/hr to 1,800 ped/hr, can be attributed to several factors:

1. The parking rates for both Stadium and waterfront parking are significantly less than parking rates within the CBD, and therefore, a great many people utilize this parking due to a considerable annual cost savings. This Stadium is the converse during major sports events at the Stadium, i.e., less expensive rates in the downtown than at the waterfront, and therefore, the direction of pedestrian movement is reversed.

2. Direct access ramps and stairs extending from all parking areas directly to the expressway ramp environment — providing easy access for pedestrians to the expressway ramps and also discouraging utilization of the two pedestrian highway overcrossings leading from the Stadium parking to the downtown.

3. The configuration, location and the excessive use of stairs and escalators at the terminals of the two highway overcrossings discourage their utilization by pedestrians. Rather than moving up, across and down, the more convenient but less safe alternative is to move at grade across the ramps into the downtown. This situation has resulted in a number of examples of pedestrian/vehicular conflicts which have a wide application to other similar situations at both macro and micro scales.

B. Elements of Linkage and Conflict:

There are six major pathways that provide pedestrian access into the downtown. Four of these are at-grade and are major free-flow exit and entrance ramps to the expressway:

1. at Main Street
2. at Vine Street
3. at Race Street
4. at Walnut Street

The two remaining alternatives are both grade-separated systems which extend from the Stadium parking decks to the downtown. However, they differ in function.

1. Pedestrian bridge — pedestrians only
2. Overcrossing — pedestrians, taxis and busses only.

The second overcrossing, which permits vehicular traffic limited to busses and taxis, represents continuous pedestrian/vehicular conflict.

Specific locations of potential conflicts occur along the extensions of Main, Race, Walnut and Vine Streets as they cross over the expressways and provide pedestrians with access across the vehicular ramps at grade level, requiring no extensive vertical displacement. The sidewalks, curbing and channeling islands, however, are completely inadequate to support and accommodate such pedestrian travel. Additional conflict points can be seen within the bus ramps from the Suspension Bridge to the bus terminal across a landscaped area, containing both a sidewalk for pedestrians and large bushes which effectively screen the pedestrians from the lines of sight of bus drivers who regularly operate their vehicles at this point in excess of 30 M.P.H. Further conflicts occur where pedestrians attempt to cross from the surface parking lots on the west of the Stadium, to the downtown area, across the expressway barrier.

Although a major accommodation has been made for pedestrian travel across the riverfront expressway area — two grade-separated bridge structures spanning the full width of the vehicular thoroughfares — its utilization is limited and conflict points at grade are still evident. This can be seen in part as due to inadequate provisions of micro-environment elements:

1. Insufficient sidewalk and curb dimensions,

2. Obstructed sight lines for drivers due to improper landscaping,

3. Driver orientation and attention to the roadway is limited due to the amount and placement of signing.

4. Insufficient lighting to accommodate for pedestrians — lighting is vehicle-directed only.

5. Pedestrian access stairs, ramps and walks meet the free-flow vehicle ramps with only the narrowest of sideway widths on which large numbers of pedestrians wait for traffic to clear the ramps.

6. The total absence of vehicle controls and devices, thereby allowing the driver to exercise his own discretion in terms of ramp speeds and making him totally unaware of pedestrians walking within the ramps.

7. Pedestrian access ramps and stairs which extend directly from areas of parking into the free-flow ramps providing easy and direct access to expressway ramps and discouraging the utilization of pedestrian highway overcrossings.

8. The absence of pedestrian countermeasures.

All of these factors contribute to the severity of pedestrian/vehicular conflicts. As can also be seen in several other prototype situations, provisions for pedestrian crossings are often negated by incomplete control measures elsewhere (countermeasures). By not completing such controls, pedestrians find more attractive means of crossing dangerous ramps and roadways — more convenient but more hazardous. Examples can be seen in the Cincinnati situation of these points of preferred but more dangerous points of pedestrian travel being consciously accommodated rather than controlled or prevented.

Of note is that the existing pedestrian bridge is remotely located for most potential users, is poorly linked to grade level at either end, and is detailed exactly like the parallel vehicular bridge and is often mistaken for such.

Alternative accommodations for the travel needs of pedestrians across the expressway barrier can be considered at both micro and macro scales. Major accommodations could take the form of additional pedestrian bridges or vehicular means of moving people across the ramps and roadways, in each case designed as more responsive to the travel desire lines of pedestrians. Micro-scale accommodations can include more complete physical control and barrier elements so as to prevent free-flow pedestrian travel occurring at points of free-flow vehicular travel. Other accommodations can include signalization to control vehicular flow or increase driver awareness of potential conflict areas, improvements in pedestrian area visibility in the form of eliminating obstacles to visibility or possibly installing mirrors to circumvent blind spots, and provisions to make existing accommodations for pedestrian travel more accessible and desirable while improving the level of safety in those surface situations.

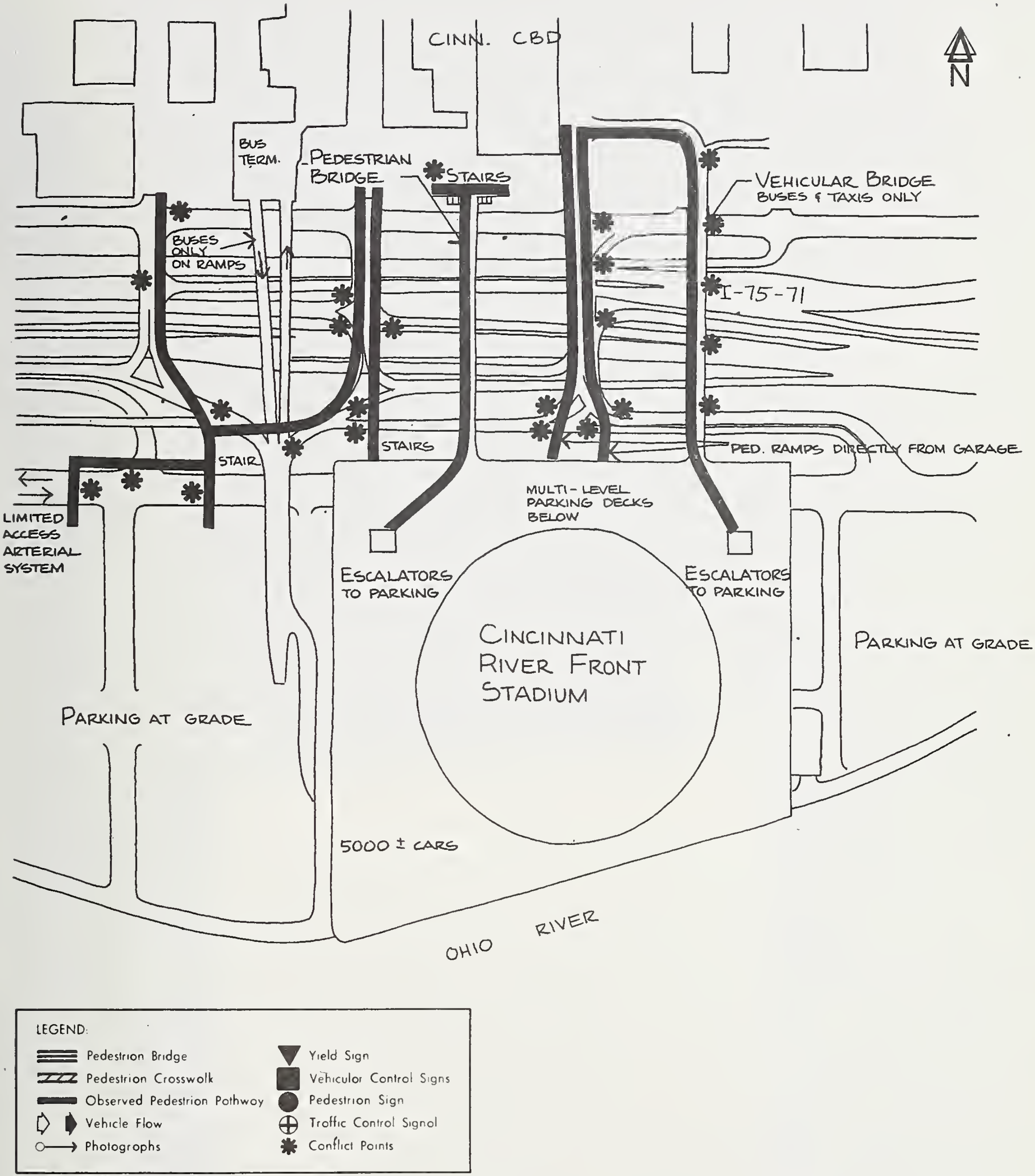

Figure 40. Cincinnati riverfront expressway.

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